DOMESTIC NUCLEAR SHELTERS

TECHNICAL GUIDANCE

A HOME OFFICE GUIDE

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Introduction

This manual of technical guidance on the design of domestic nuclear shelters has been prepared by a working group set up by the Emergency Services Division of the Home Office. The working group was asked to consider designs of nuclear shelters which could be made available to members of the public in the United Kingdom who might wish to purchase and install shelters for the use of themselves and their families.

The working group realised that the range of designs which it might produce would not be exhaustive. However, it was aware of the need to give technical guidance to professional engineers to assist them in producing reliable shelter designs. Thus the first three chapters of this book are written to give such guidance.

The other four chapters of the book give detailed designs of five shelters. These five cover a range of types which are applicable to different sorts of houses; they also cover a wide price range. These designs are not intended to be exhaustive, and as explained in the text, the working group is already giving attention to other designs, particularly those which might be incorporated into existing or new houses and also underground shelters of shapes other than box-like and using materials other than concrete. It is planned to publish details of this work at a later date.

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To obtain some protection from the heat it is necessary to move out of the direct path of the rays from the fireball; any kind of shade will be of some value. In shelter design, any materials affording protection against ionising radiation or blast will give more than adequate protection against the heat. However it is important to ensure that no exposed parts of the shelter (such as the facings of doors) are made of flammable materials. In the case of shelters made from plastic materials such as GRP (glass reinforced plastic) it is essential that no surfaces should be exposed to the heat pulse. It is unlikely that such plastic materials would catch fire, but they may melt or distort. Since the blast wave follows the heat pulse, such distorted areas may result in lowered blast resistance.

It is considered unlikely that the heat flash from a nuclear explosion would give rise to fire-storms. In the last war, fire-storms were caused in the old city of Hamburg as a result of heavy incendiary attacks and at Hiroshima but not at Nagasaki. A close study of these cities and of German cities where fire-storms did and did not occur revealed several interesting features. A fire-storm occurred only in an area of several square miles, heavily built up with buildings containing plenty of combustible material and where at least every other building in the area had been set alight. It is not considered that the initial density of fires, equivalent to one in every other building, would be caused by a nuclear explosion over a British city. Studies have shown that due to shielding, a much smaller proportion of buildings than this would be exposed to the heat flash. Moreover, the buildings in the centres of most British cities are now more fire-resistant and more widely spaced than they were 30 to 40 years ago. This low risk of fire-storms would be reduced still further by the control of small initial and secondary fires.

There are two main hazards from a large area of fire to the occupants of shelters. One is the transmission of heat through the earth and shelter wall. In most cases this would make for discomfort rather than danger, particularly in underground shelters. The major danger is the possibility that the gaseous products of combustion, mainly carbon dioxide and perhaps carbon monoxide, might be drawn into the shelter. These dangers may be mitigated by taking advantage of the fact that the arrival of fallout is unlikely to occur for about half an hour after the explosion and a fallout warning will be given (for details see the booklet *Protect and Survive*). The intervening time might be used to try to extinguish or damp down any nearby fires. This may not be possible in many cases where a fallout warning has already been given based on ground bursts further upwind than the local bomb.

Crater formation and ground shock

When a nuclear weapon bursts near the ground much of the energy is expended in making a crater. At the same time a shock wave is transmitted outwards through the ground.

Crater formation

A large amount of vapourised or pulverised material is sucked up by the ascending fireball. Larger amounts are gouged out and deposited on the perimeter of the crater making an elevated lip roughly equal in width to the radius of the crater itself. The size of the crater, for a weapon of given power, will depend on the nature of the ground and

Fig. 6 ***Approximate ranges of blast damage to UK houses (from 1 MT groundburst)***

Designation	Radial distance	Overpressure	Effect	Death/injury
A ring	Up to 2.5 km (1½ mi)	77 kPa plus. (11 psi)	Houses totally destroyed	High probability of death or serious injury
B ring	2.5 to 3.5 km (1½ to 2¼ mi)	77 to 42 kPa (11 to 6 psi)	Houses irreparably damaged	About 10% killed; 35% trapped; others injured
C ring	3.5 to 9 km (2¼ to 5½ mi)	42 to 10 kPa (6 to 1.5 psi)	Houses with moderate to severe damage	About 25% trapped or seriously injured at inner edge of ring
D ring	9 to 14 km (6 to 9 mi)	10 to 5 kPa (1.5 to 0.75 psi)	Houses lightly damaged	No deaths; few injuries expected

(WWII house damage vs injury data)

The debris problem

From Fig. 6 it can be deduced that the problems of debris around buried shelters might be serious in some locations near to ground zero. It is important that entrances or escape hatches and ventilation pipes where included should be as far as possible from nearby buildings — at least a distance equal to one-half the height (measured to the eaves) of the nearest building.

Trees are very vulnerable to long duration blast waves and in some areas these might cause obstruction to shelter entrances. The blast from a 1 MT groundburst would blow down 90 per cent of trees at a distance of 6 km (3¾ miles), 30 per cent at 7 km (4½ miles) and cause damage to branches out to 10 km (6¼ miles).

Initial nuclear radiation (INR)

Neutrons and gamma rays are emitted instantaneously by a nuclear explosion and these are followed by the gamma radiation from the intensely radioactive products in the fireball. This radiation is called initial nuclear radiation and is defined as that radiation emitted within one minute after detonation. In fact most of this hits the ground within a few seconds since the rapid rise of the fireball quickly takes the gamma rays and neutrons out of range. The phenomenon of initial nuclear radiation is very complex and not completely understood, but four facts are of importance for shelter design.

1. Range of INR

The intensity of INR falls off very rapidly with distance. The dose of INR received by a person in the open 2.5 km (1½ miles) from a 1 MT burst would give only a 50 per cent chance of survival. At 2.8 km (1¾ miles) the dose received would be negligible. At those distances, of course, anyone in the open would be killed by the blast. One important difference between kiloton and megaton weapons is the relationship between blast and INR ranges. With the smaller kiloton weapons the range of INR extends beyond the range of lethal blast; the reverse is true for megaton weapons. The Hiroshima and Nagasaki weapons were in the kiloton range and produced lethal INR effects. Fig. 7 gives the approximate exposures in roentgens of INR at locations where the blast overpressures are significant. Shelters designed to withstand a given overpressure should also be designed to protect against this level of INR. Overpressures are given in kiloPascals (psi).

Fig. 7 ***Exposures of INR from surface burst (in roentgens)***

Overpressure	315 (45)	105 (15)	77 (11)	42 (6)	10 (1.5)	5 (0.75)
100 KT	300,000	20,000	9000	500	<1	<1
1 MT	70,000	1,000	250	2	<1	<1
10 MT	20,000	15	<1	<1	<1	<1
20 MT	9,000	1	<1	<1	<1	<1

Exposure would be lower from air bursts of the same weapon power. The figures given refer to thermonuclear weapons with 50 per cent fission yield. These figures may vary from 25 per cent to 150 per cent of the values given in the chart.

2. Shielding for INR

INR has greater energy and penetration than the radiation from fallout. The intensity of both INR and fallout radiation are reduced in proportion to the density of the shielding material. This can be expressed in terms of the 'half-value thickness' which is the thickness of a particular shielding material required to halve the radiation dose-rate. The approximate half-value thicknesses of some shielding materials against INR are given in Fig. 8.

Fig. 8 ***Half-value thicknesses of shielding materials***

	Against INR		Against fallout radiation	
	mm	(inches)	mm	(inches)
Steel	38	(1.5)	18	(0.7)
Concrete	152	(6.0)	56	(2.2)
Earth	190	(7.5)	84	(3.3)
Water	330	(13.0)	122	(4.8)
Brickwork	157	(6.2)	71	(2.8)

The half-value thicknesses of these materials against fallout radiation are given for comparison. They will be referred to later.

3. Slant incidence of INR

Most of the INR from a nuclear explosion arriving at a given point comes in a direct line from the fireball. There is a certain amount of scattering known as 'skyshine' which means that some initial gamma radiation might be received by a person shielded by a barrier from the light and heat flash (see Fig. 10). The amount of scattering of initial gamma radiation depends upon a number of factors, but probably amounts to about 10 per cent of that in the main beam. This means that though an underground or semi-sunk shelter might be shielded from the major part of the initial gamma radiation a certain amount could be received through the roof or sides of the shelter (if semi-sunk) by what is known as 'angular distribution'. However this benefit of shielding by nearby buildings cannot be taken into account in calculating the protection afforded by a shelter since the location of the source of the initial gamma radiation cannot be known.

4. Rate of emission of INR

The rate of delivery of initial nuclear radiation has some relevance to actions that might be taken immediately after a nuclear burst. Fig. 9 gives the percentage of initial gamma radiation dose received as a function of time for 20 KT and 5 MT air bursts. It can be seen that in the former case about 65 per cent and in the latter case 5 per cent of the total initial gamma radiation dose is received during the first second. In the case of the higher yield weapon it can be seen that if some shelter could be obtained within one second of seeing the explosion flash, such as by falling prone behind some substantial object, it could make the difference between life and death. Such an action would also help to prevent the translational effect of the blast.

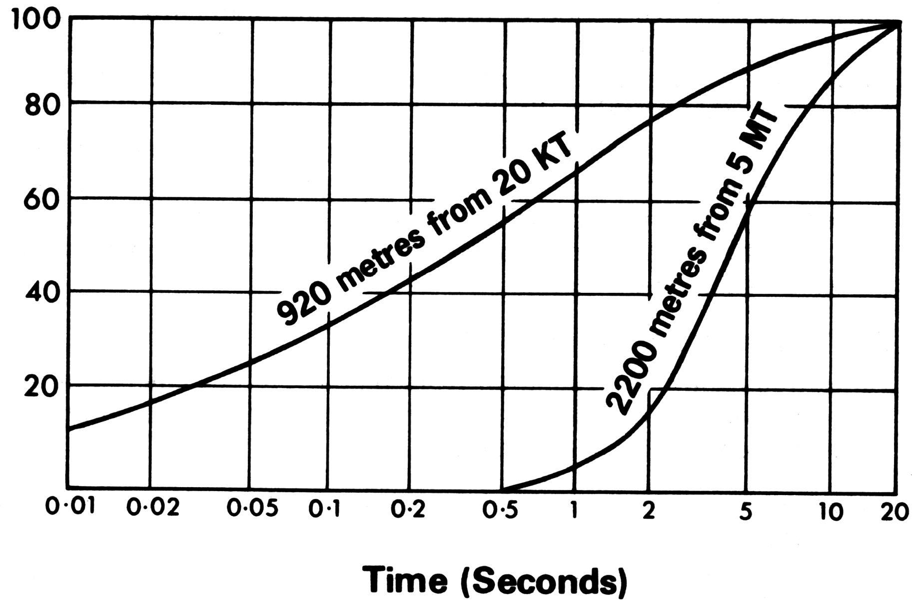
Residual radiation from fallout

Nature of fallout

Fallout from a groundburst weapon consists of molten and solidified particles of earth on to which the radioactive products of the detonation have condensed. It has the consistency of fine to coarse sand particles with size varying from 20 to 700 micrometres. Particles smaller than about 20 micrometres would most probably remain in the stratosphere and come down as late fallout weeks, months, or even years later; by this time their radioactivity would have decayed considerably. The fall times from various heights of particles of various sizes are given in Fig. 11.

The time taken for fallout to be deposited in any one place varies from about half an hour close to the explosion to many hours further downwind. It is particularly important that people get under some kind of cover during this period to avoid fallout particles getting on the skin. Anyone who is caught out during fallout deposition should certainly cover the head and exposed skin and remove the contaminated clothing before entering shelter. No special protective clothing is required since no kind of clothing will prevent the gamma radiation from fallout reaching the body. If anyone has to emerge from shelter after the fallout has been deposited on the ground it would be useful to wear waterproof boots and gloves with a coat over the indoor clothing. Again these should be removed before re-entering the shelter. Any exposed skin should be washed after any contact with fallout particles.

Fig. 9 *Percentage of total initial gamma dose received*



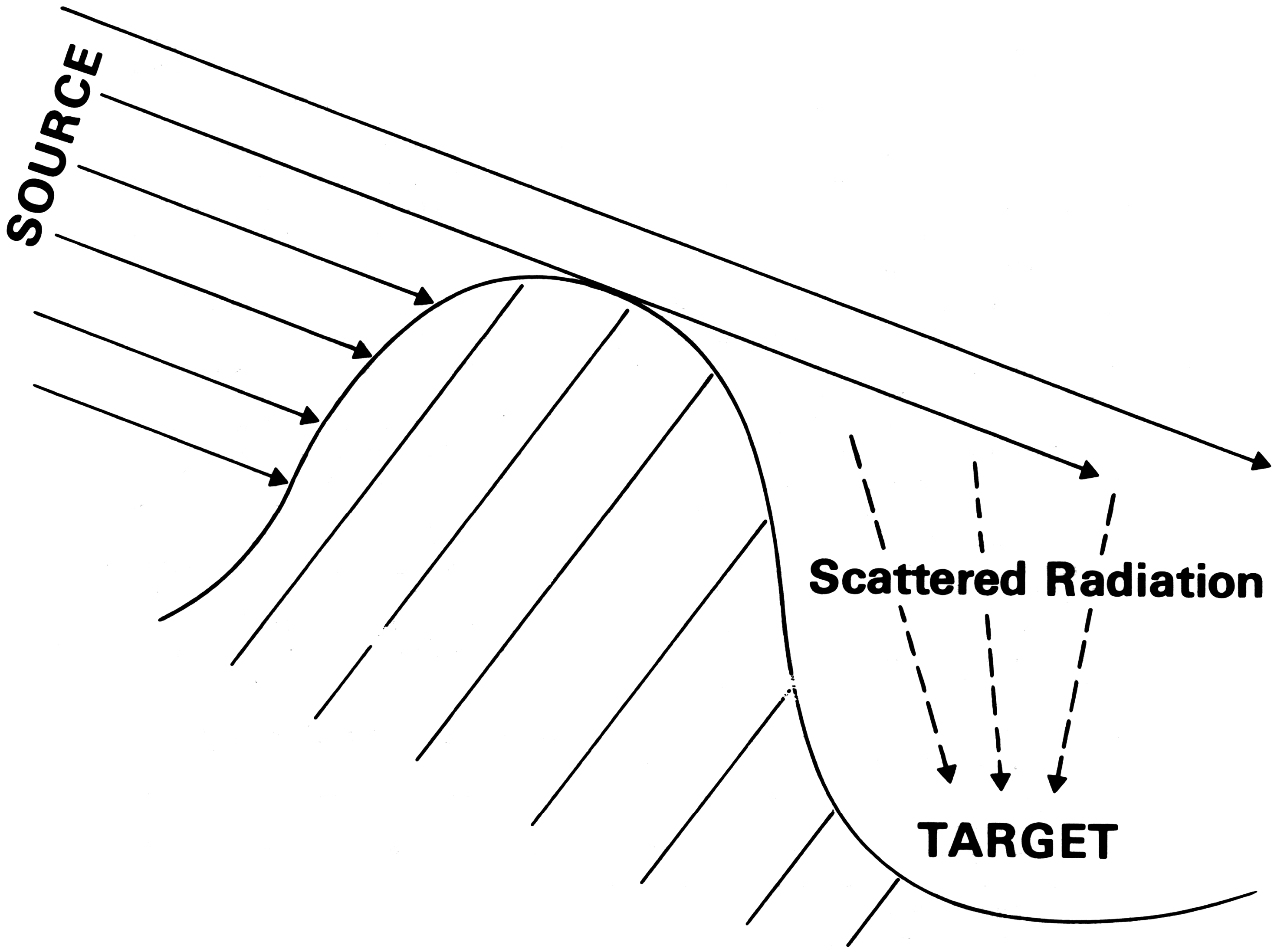


Fig. 10 *Target exposed to scattered gamma radiation from a nuclear burst*

The nature of fallout particles has an influence on the filtration requirements for shelters. If the air coming into the shelter follows a tortuous path such as is provided by an inverted U shape or a cowl over the air intake, the need for filtration is minimised, if not entirely eliminated. The fallout particles will tend to fall to the earth rather than be carried along by the air current into the air duct. In any case the fallout particles are in the air for a limited period of time in the early hours after the burst so that if filtration is thought desirable, it need only be for that limited time. It would however be better to avoid drawing air into the shelter whilst the fallout is being deposited, if it is possible to know when this is taking place.

If a filter is incorporated into shelter design two points should be considered. The first is that a coarse filter is all that is necessary; a fine filter runs the risk of becoming blocked by ordinary atmospheric dust with resultant reduction of air supply. The second point is that if a filter is likely to become contaminated with radioactive dust then it should be placed outside the shelter.

Protection from fallout radiation

Protection against the radiation from fallout can be achieved in three ways. Consideration must be given to *duration* of exposure, *distance* from the fallout, and *density* of materials between the person and the fallout.

Duration. The damage caused by radiation to the body is cumulative (although the body does show a capability of some recovery). Thus it is important to reduce the time of exposure to radiation. In addition to this the radioactivity from fallout decays in a predictable manner by what is known as the '7/10 law'. Thus a dose rate of 1000 roentgens per hour at one hour after burst will decay to 100 roentgens per hour at seven hours after burst and 10 roentgens per hour at 49 hours (or two days) after burst and so on. This rapid decay means that, except in very severely contaminated areas, it is unlikely that anyone would have to stay continuously in shelter for two or three weeks. Local authorities will tell people when the intensity of the radiation has fallen to levels which make it safe to emerge from shelter for one or more hours. This time, which will gradually increase, can be used to ventilate the shelter better and attend to necessary tasks.

Distance. Protection can be achieved too by keeping as far away from the fallout as possible. A person standing on ground evenly contaminated by fallout would receive half his radiation dose from a circle of about 7.5 metres around him. Thus the floor of an underground shelter or a position in a house as far as possible from the roof and outside walls offers the best protection.

Density. The most important way of reducing the intensity of radiation is by sheltering behind some dense material. As explained, the level of radiation is reduced as it passes through any material but the greater the density of the material, the greater the reduction. The thickness of some materials required to reduce the intensity of fallout radiation to one half were given in Fig. 8. Glass gives little or no protection against radiation and many light materials, such as clothing, bedding etc., afford little protection. However, shelters can be constructed from such materials as glass reinforced plastic (GRP) which does not give much protection itself but can be buried in the ground; the earth cover then will give protection. A layer of 375 mm (15 inches) of earth or 250 mm (10 inches) of concrete over a shelter area would reduce the intensity of the radiation inside the shelter to 1/100th of the intensity outside. This reduction is called a protective factor (PF). A method for calculating protective factors is given in Chapter 2. It is designed for calculating the PFs of buildings. When applied to buried shelters the table dealing with penetration through the roof may be all that is needed.

Fig. 11 ***Time in hours for rough particles of different sizes to fall to the ground from specific heights***

Particle diameter in microns	500	350	200	100	75	50
Falling from metres (feet)						
25,000 (80,000)	1.6	2.3	4.5	12	22	49
18,000 (60,000)	1.3	2.0	3.7	9.5	17	36
12,000 (40,000)	1.0	1.5	2.8	6.8	12	25
9,000 (30,000)	0.8	1.2	2.2	5.3	9	19

Further comments on protection against INR and fallout radiation

From Fig. 7 it can be seen that a person on the outer edge the 'A' ring at 77 kPa (11 psi) from a one megaton explosion might receive a dose of about 250 rads INR. This would not in itself be lethal and even some rudimentary shelter would reduce the dose. At this same point the proportion of the population in houses surviving though injured might be about 40 per cent. Nearer to the point of burst the survivors would be fewer but the INR higher. It is in fact in the areas where blast shelters can give the greatest saving of life that INR becomes important, and so must be protected against. As a general rule, shelters designed to protect against 77 kPa (11 psi) and above should also give protection against INR. In most cases however, the required thicknesses of earth, concrete, etc. to give blast protection will also give the required INR protection.

Fig. 12 gives a comparison of the protective factors against INR gamma, neutrons and fallout radiation of some typical buildings. The data has been taken from *Effects of Nuclear Weapons* and the choice has been made of those buildings which are reasonably comparable with structures in the UK. The wide range of values is due partly to uncertainty in the data (since some have been calculated and others derived from weapons trials) and partly to the fact that protection to some extent is determined by the position in the building where the protective factor is measured.

Fig. 12 ***Protective factors of various buildings against initial gamma, neutron and fallout gamma radiation***

Structure	Initial gamma	Neutrons	Fallout gamma
1 metre underground	250–500	100–500	5000
Shelter partly above ground: with 600 mm earth	15–35	12–50	50–200
900 mm earth	50–150	20–100	200–1000

Classification of shelters

Summary of effects of nuclear weapons

From this brief review of the effects of nuclear weapons we can list the order of events from the detonation of a weapon. These are:

(a) Light and heat flash – immediate, and lasting some seconds.

(b) Initial nuclear radiation – following within one second of the commencement of the light flash.

(c) Blast wave – following from about a half second to several seconds after the light and heat flash.

(d) Fires – these may have been ignited by the heat flash but would be either extinguished or increased in intensity by the wind from the blast wave.

(e) Fallout – about one half hour to several hours after burst.

Protection against all these effects can be summed up by stating that distance from the source of the hazard and density of shielding materials give the best, and indeed the only, means of avoiding serious injury or death. The two major hazards in this list are blast and radiation. Adequate protection against these two will include protection against the others. It can indeed be said that adequate protection against blast will usually involve protection against radiation. The reverse however is not true. In spite of this, however, it is worthwhile looking at the need for protection in the whole of the United Kingdom.

Considerations arising from the probable attack pattern

In section 1.1.1 reference was made to the fact that an expected attack pattern on the United Kingdom might use 200 megatons on about 80 targets. If we now make an assumption that this attack would be in the form of 100 weapons of 1 MT airbursts and 100 weapons of 1 MT groundbursts we can use the information given in Fig. 6 to indicate the probability of areas being subject to various effects.

On this assumption, we should find that about 2.2 per cent of the land area of the UK would be subject to overpressures in the 'A' ring of 77 kPa (11 psi) and above about 1.8 per cent would be subject to overpressures of between 42 and 77 kPa (6-11 psi) in the 'B' ring and about 10 per cent of the land area would be subject to overpressures of between 10 and 42 kPa (1.5 to 6 psi). The rest of the land area, about 85 per cent, would be subject to blast in the D ring of 5 to 10 kPa (0.75 to 1.5 psi) or to no blast at all. Blast effects in the D ring will cause minor damage to buildings and no lethalities. It is impossible to determine the extent of the total D ring areas since many of these will overlap from adjacent bombs. Any part of the country might be subject to radiation from fallout.

There is of course no certainty of where the weapons will fall – and city centres are not necessarily the prime targets – but this consideration leads us to group shelters into various types and assess the probability of survival in given circumstances. It should of course be obvious that within about 450 metres (1500 feet) of a 1 MT groundburst no shelter can give any hope of protection. But the following grouping of shelters has some cogency.

Fig. 13 ***Classification of shelters***

	Type 1 Improvised	Type 2 Indoor Kit	Type 3 Outdoor Kit	Type 4 Purpose built
Blast protection kPa (psi)	Up to 10 (1.5)	Up to 42 (6)	Up to 77 (11)	In excess of 77 (11)
Fallout radiation protection	Not less than 40	Not less than 70	Not less than 200	In excess of 300. This type must also protect against INR
'Safety distance' from 1 MT airburst km (miles)	11.5 (7)	5 (3)	3.3 (2)	3.3 (2) for 77 kPa (11 psi) 3 (1.8) for 105 kPa (15 psi) 2 (1.2) for 315 kPa (45 psi) shelter
Ventilation	Natural	Natural or forced	Forced	Forced
Site of installation	In house† or garden	In house	In garden. Sectional for access through house	In garden. Appropriate access to garden necessary (See 1.3.4)
Forethought and planning	During crisis period. Some materials can be prepared in advance	Obtain in peace-time. Install in crisis period	Obtain in peace-time. Install in peace-time or crisis period. (2-3 days needed for installation (see 6.5)	Install in peace-time using professional advice and help.
Habitability	Not very comfortable. Suitable for few days occupancy. May be damp. Floor covering desirable	Able to sit up but not stand. May be able to use parts of house depending on radiation and damage situation	Rather cramped for 6 people; advance planning can improve comfort	Can be made very comfortable and habitable
Approximate expected cost (1980 prices)	Nominal if local materials used. Scaffold frame about £250	Kit: £500–£800 Bricks: £300	Kit: £900–£1800 Plus installation costs*	£6000–£10,000

*Installation costs will vary with nature of soil and nature of access to garden.
†E.g. The measures described in *Protect and Survive*.

Further comments on Home Office shelter designs

Chapters 4 to 7 of this book give details of the Home Office shelter designs and, where appropriate, detailed instructions for construction. It will be useful however to discuss here the reasons why this range of shelters has been chosen. Other designs are under consideration and it is planned to make details of these available later.

Limitations related to houses and gardens

In making recommendations for shelters it has been necessary to keep in mind the varying needs governed by the types of housing in the United Kingdom. Very roughly housing can be divided into the following groups:

a. Detached or semi-detached houses where there is appropriate access to the rear garden. (About 34%).
b. Semi-detached and terrace housing where there is no access to the rear garden, except through the house. (About 20%).
c. Houses with no rear garden. Such houses usually have a passage between the rows of terraces with access to a back yard. (About 25%).
d. Multi-storey blocks of flats. (About 12%).
e. Flats resulting from the conversion of 2, 3 and 4 storey houses. There is usually some garden space available attached to such property. (About 7%).
f. Bungalows, usually with accessible gardens. (About 2%).
g. Caravans.

The shelter types in Fig. 13 are designed for use in these housing groups as follows:

Type 1 Groups a, b, c, f, possibly d, e and g.
Type 2 Groups a, b, c, f, possibly d.
Type 3 Groups a, b, f, possibly e.
Type 4 Groups a and f.

It will be seen that all groups of housing are covered except possibly for d and only minimally for e and g. Further consideration will be given to shelter provision for those in group d and also upper storeys of group e. However, we believe that one or more of our shelter types will be suitable for installation in the majority of the houses in the country.

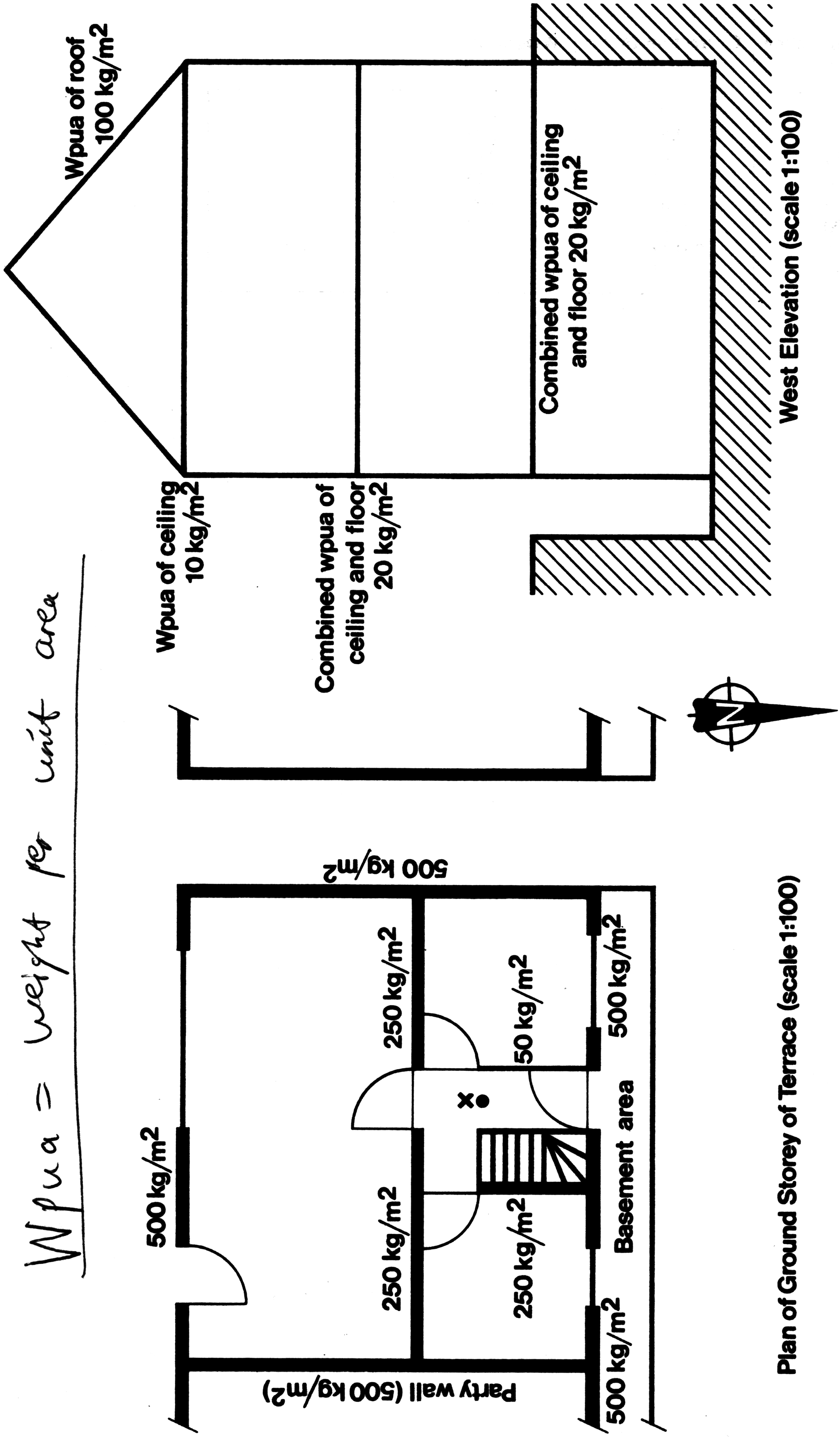
Type 1 shelters

A 'core shelter' for use inside a house has already been described in ***Protect and Survive.*** Its life-saving potential should not be minimised. The details of the two improvised shelters in Fig. 13 are given in later chapters. The construction of these shelters has been carried out by volunteers satisfactorily. They were given a short time to read the instructions before carrying out the work. Although these are all designated improvised shelters, some thought can be given in advance to the procurement of materials for their construction, thereby eliminating the need to remove doors, etc. from the house.

Type 2 shelters

This type is designed for houses where there is no suitable ground attached to the house on which to install a shelter. It is in essence a 'core shelter' which will protect the occupants from the debris of a house that is severely damaged. The radiation protection factor is obtained by shielding it with bricks, blocks, sand, furniture, books, bags of soil, etc. It is designed to withstand the debris from a two- or three-storey house falling on it. However, it is probable that the debris from a three-storey house may make it difficult for the occupants to dig themselves out. The 'blast protection' indicated is that at which most houses would receive irreparable damage and there would be a considerable amount of debris on the shelter.

The details of this shelter are given in Chapter 5. This is not the only possible shape; further studies are underway which should result in different designs of the 'Indoor kit-type' shelter.



West Elevation (scale 1:100)

Plan of Ground Storey of Terrace (scale 1:100)

Wpua = weight per unit area

Chapter 5
Indoor kit shelter design

"Morrison shelter" of 1941 (indoor steel table shelter)

General

This chapter gives information about an indoor shelter suitable for erection in homes that have basements or rooms that can be converted into a fallout room. It can be used as the 'inner refuge' referred to in the Home Office booklet *Protect and Survive* and anybody considering purchasing or using such a shelter should read *Protect and Survive* and be totally familiar with its contents.

The shelter will accommodate two adults and two small children. Two or more shelters can be placed together to gain more shelter area.

It should be stored in a clean dry place, ready for erection if required, *and could be used for other purposes, e.g. a workbench in a garage or garden shed.*

Shelter details

The indoor kit-type shelter is shown in Fig. 64.

A specialist steelwork fabricator will need to cut, weld, paint and drill bolt holes for the steel parts. However, once the units have been manufactured the shelter can be erected by unskilled labour. (Two persons two hours each.) Steelwork shop fabrication drawings are given in section 5.11, a steelwork specification in 5.10 and a guide to putting up the shelter in 5.12.

The basic unit has been designed to be capable of sustaining the debris load resulting from the complete collapse of a typical two-storey house, and when surrounded with brickwork, sandbags or other protective materials it will provide good protection against fallout.

Location of shelter

Where the shelter can be used

In two-storey houses and the lower floors of blocks of flats of substantial reinforced concrete or steel-framed construction, in areas where the density of building is comparatively low.

Where the shelter should not be used

1. Houses that have more than two storeys.

2. On the upper floors of houses or any ground floor that has a basement directly below it.

3. Blocks of flats having load bearing brickwork, blockwork or precast concrete panel construction.

4. The top two floors of a block of flats.

5. Lightly clad buildings.

Location of shelter in fallout room

As explained in *Protect and Survive* the shelter should be placed within the fallout room. Choose the place furthest from the outside walls and from the roof, or the room which has the smallest amount of outside wall or openings. The entrance should be positioned facing a solid internal wall wherever possible (see Fig. 65). A gap of 600 mm should be left between the outside of the fallout protection around the shelter and the walls of the fallout room to facilitate emergency escape.

The shelter should be placed on the most solid base available. When the shelter is to be placed on a suspended ground floor, this floor may require strengthening by providing additional piers, walls or props to support the floor joists.

Protecting the shelter against fallout radiation

Fallout protection to the shelter can be obtained by surrounding it with dry-laid brickwork, blockwork, sandbags, or heavy furniture filled with sand, earth or books (see Figs. 66 and 67). Recommended thicknesses of shielding materials are given in the following table:

Fig. 61 ***Recommended thicknesses of shielding materials***

	Thicknesses		
	To sides		To top
	Sides facing external walls	Sides facing solid internal walls	
Brickwork	1½ bricks (343 mm)	1 brick (225 mm)	4 courses bricks (260 mm)
Dense blockwork	1½ blocks (330 mm)	1 block (225 mm)	3 courses blocks (300 mm)
Sandbags	350 mm	250 mm	300 mm

If bricks or blocks are used they should be dry-laid, but closely packed and bonded so as to stagger the joints as much as possible. Suggested bonding is shown in Fig. 68.

Fallout room

External windows and doors in the room containing the shelter should be blocked up with material of the same weight as the surrounding wall. A 600 mm by 600 mm dry-laid area should be left within the blocked-up area to provide an escape exit.

For shelters protected as described, protective factors are given in the following table:

Fig. 62 *Approximate protective factor*

House type	Protective factors	
	House with all exterior windows blocked	House with exterior windows blocked plus shelter and bricks
Terraced: traditional	15	260
Terraced: modern	11	140
Semi-detached: traditional	12	210
Semi-detached: modern	9	130
Detached: traditional	10	180
Detached: modern	8	110

Provision of emergency escape tunnel

Materials

Use tables, doors and other items of heavy furniture to form an emergency escape tunnel. As for *ad hoc* shelters, other structural commodities might be utilised for building escape tunnels. Fig. 69 shows how scaffold poles could be used for the purpose.

Location of escape tunnel

The escape route should be planned so that it emerges near to an opening in an external wall. If external openings are blocked up, a weaker escape knock-out area (e.g. dry-laid bricks or blocks 600 mm by 600 mm) should be provided.

Tools and materials required

For construction

16 mm and 10 mm spanners (1 open, and 1 ring, of each).
Steel lever for lining up holes.
Work gloves.

For shelter

Recommended quantities of materials for fallout protection are given in the following table. (Figures in table for entrance shielding wall, but do not consider materials required for blocking up openings in external walls.)

Fig. 64 ***Indoor kit-type shelter***

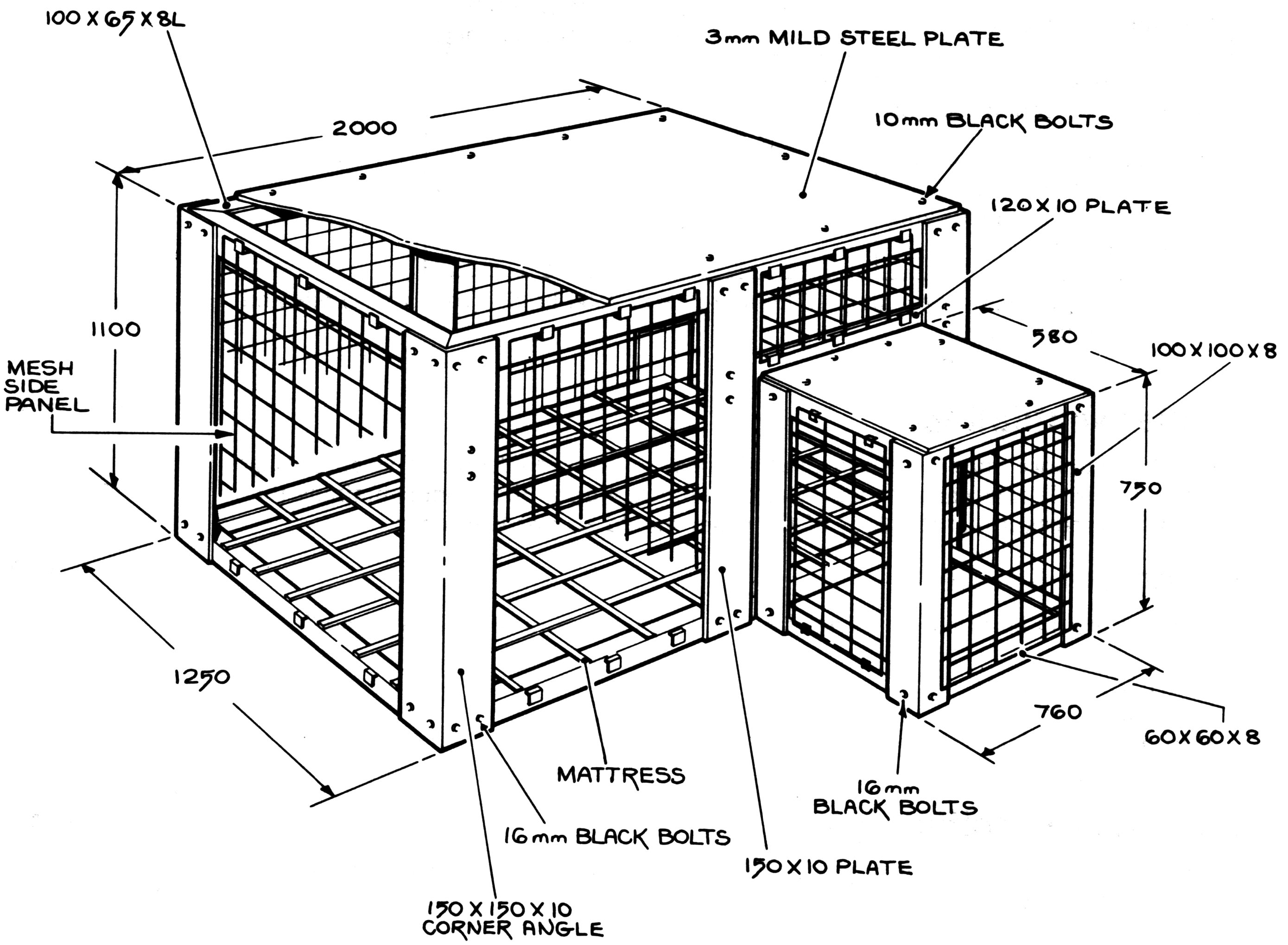
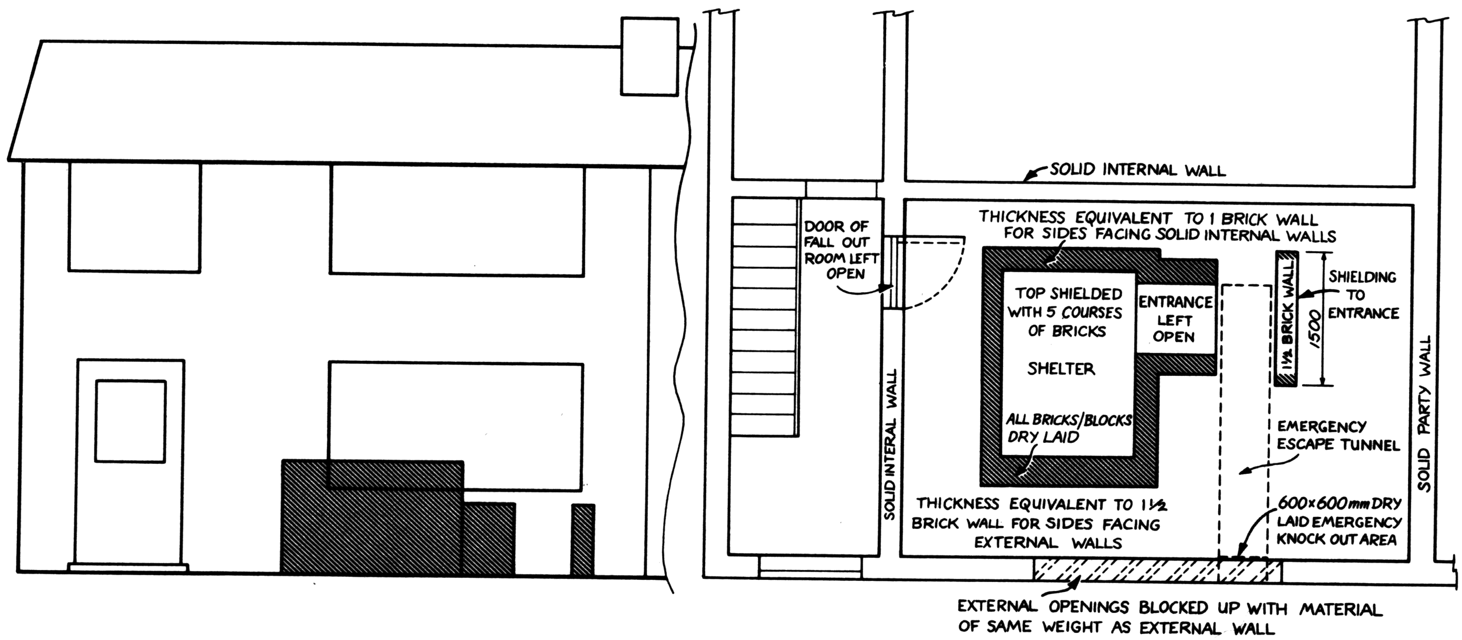


Fig. 65 ***Location of shelter***



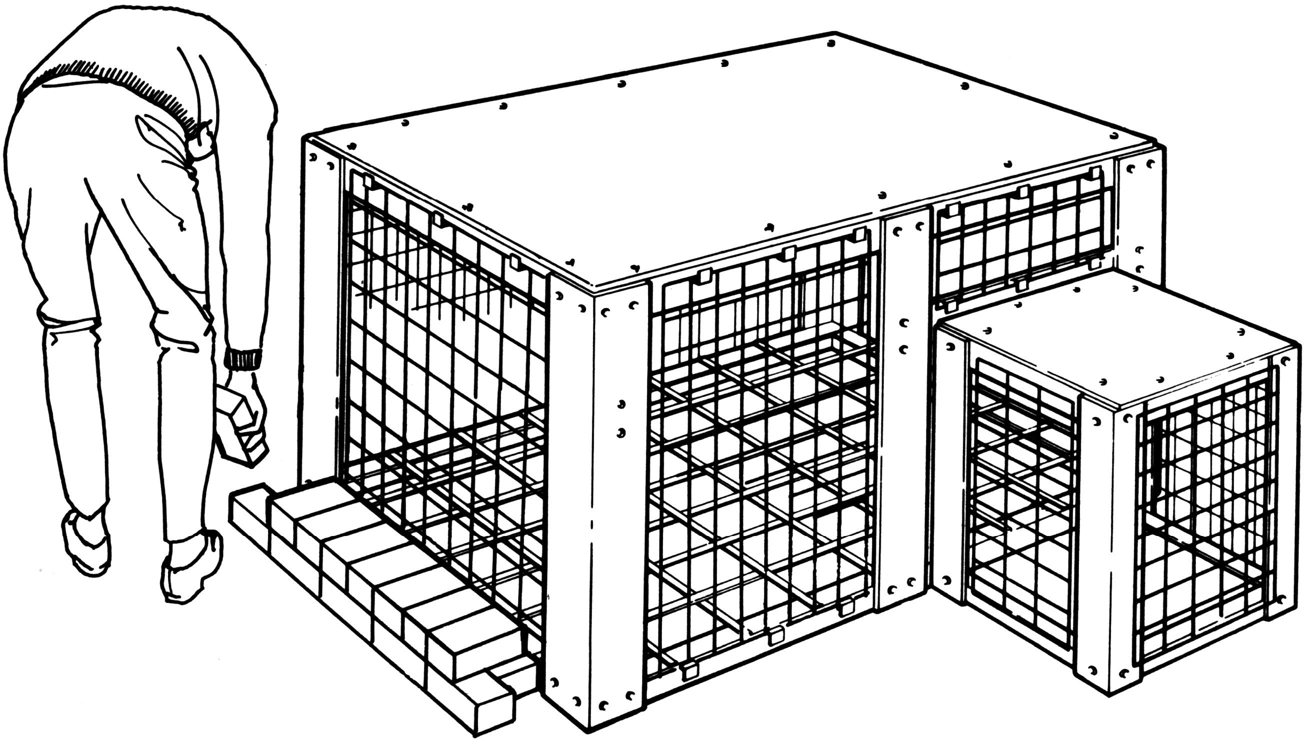


Fig. 66 ***Shelter surrounded with bricks***

Fig. 67 ***Shelter surrounded with sandbags***

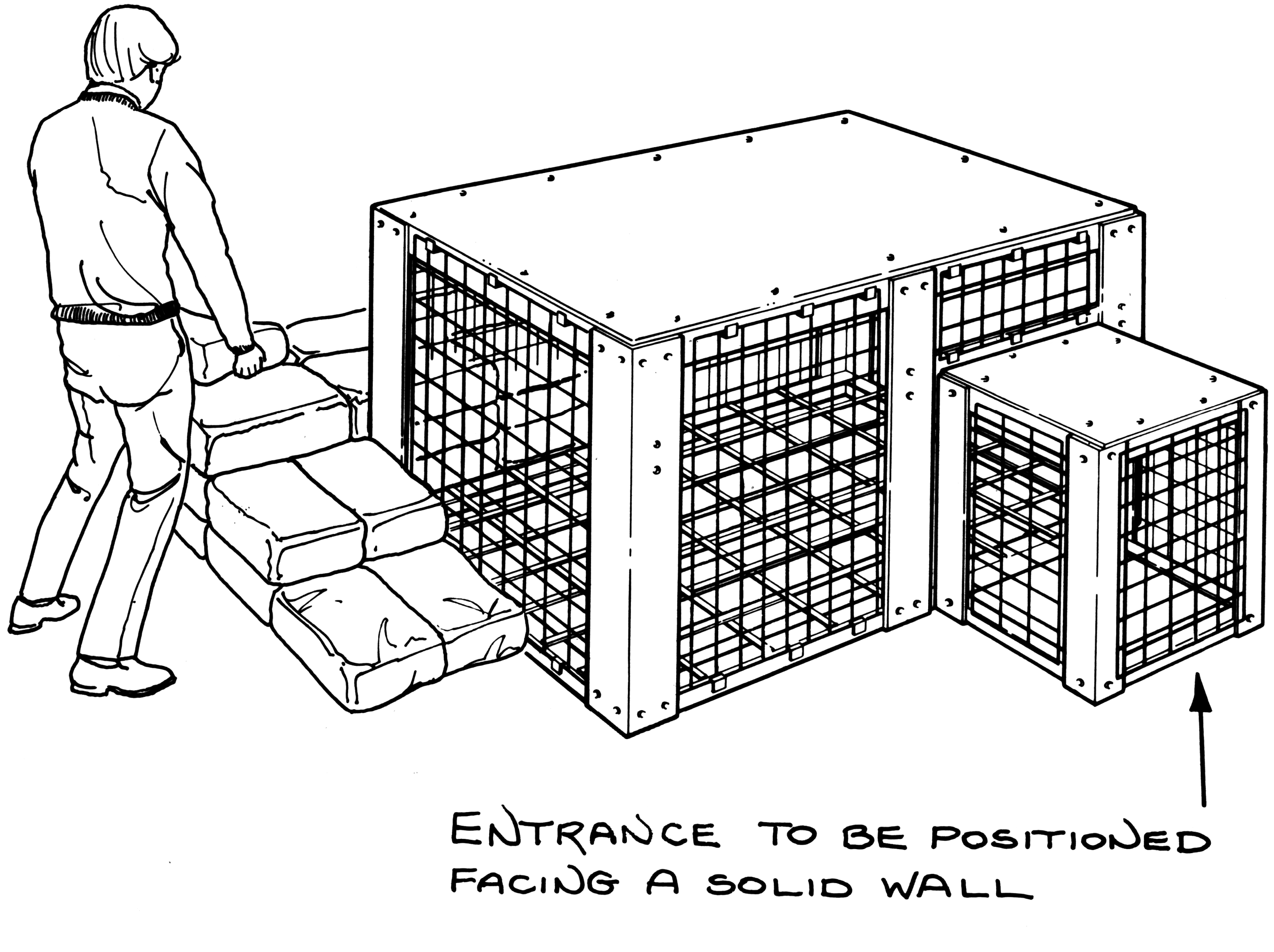
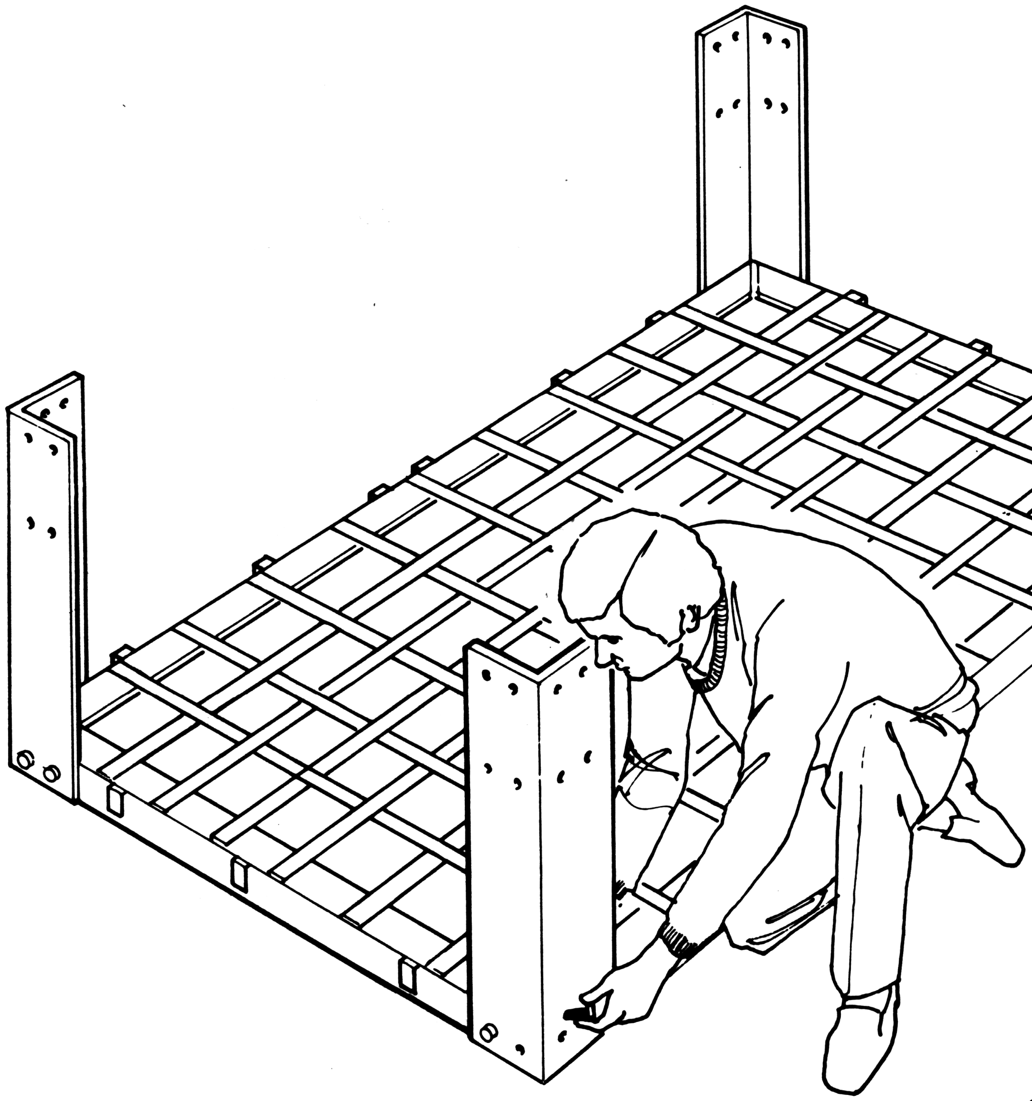


Fig. 79 *Erection drawings*



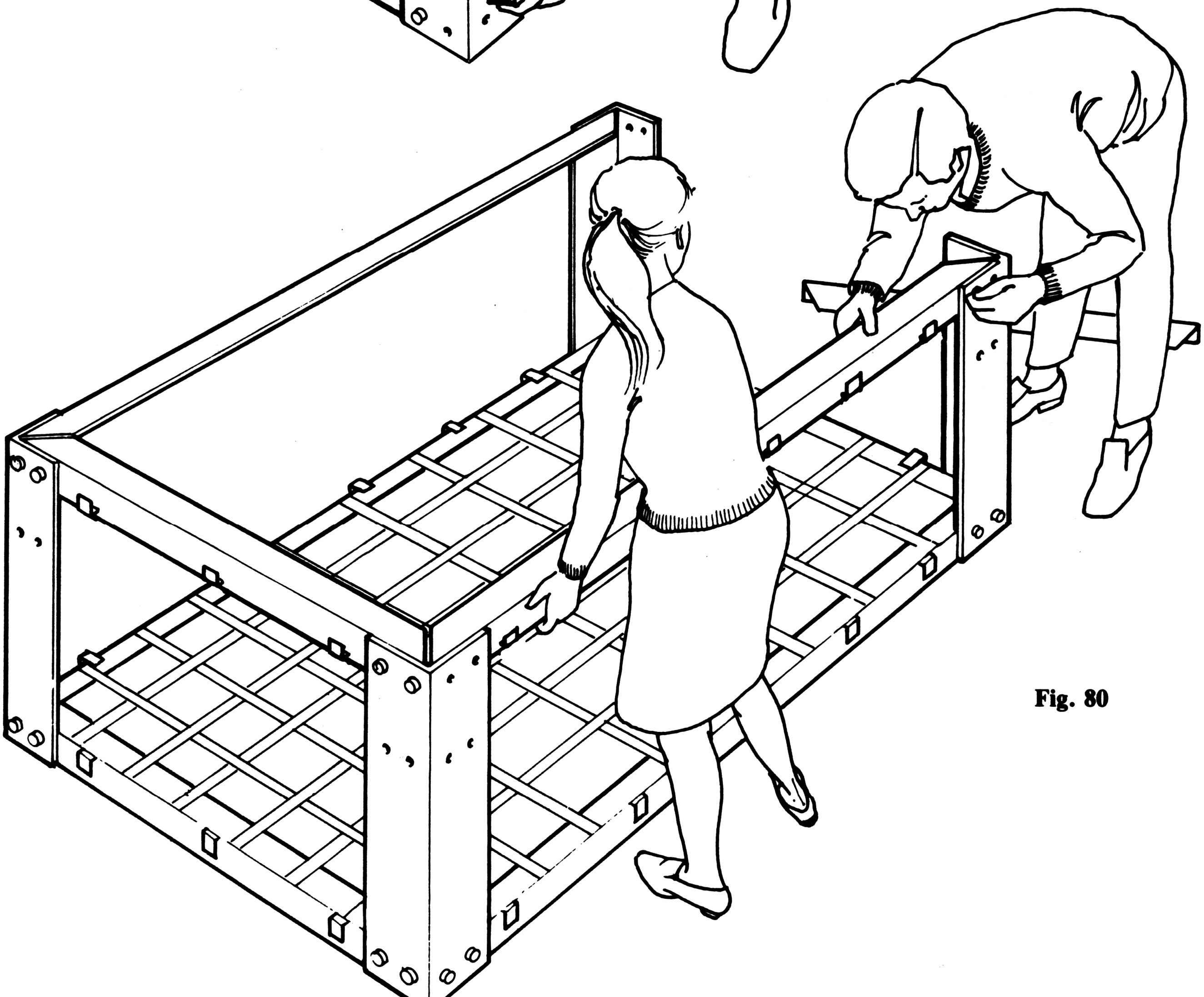


Fig. 80

Fig. 81

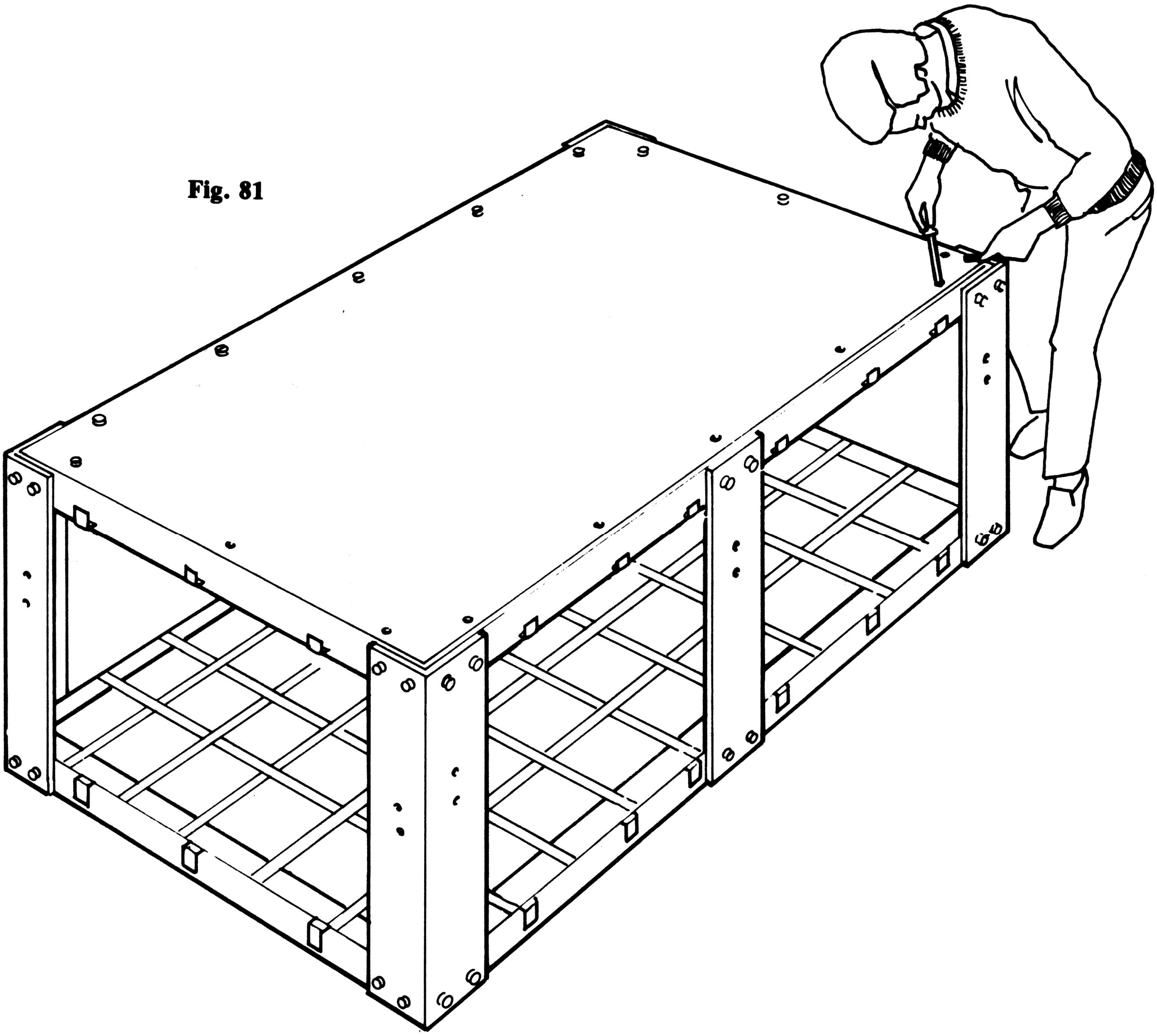
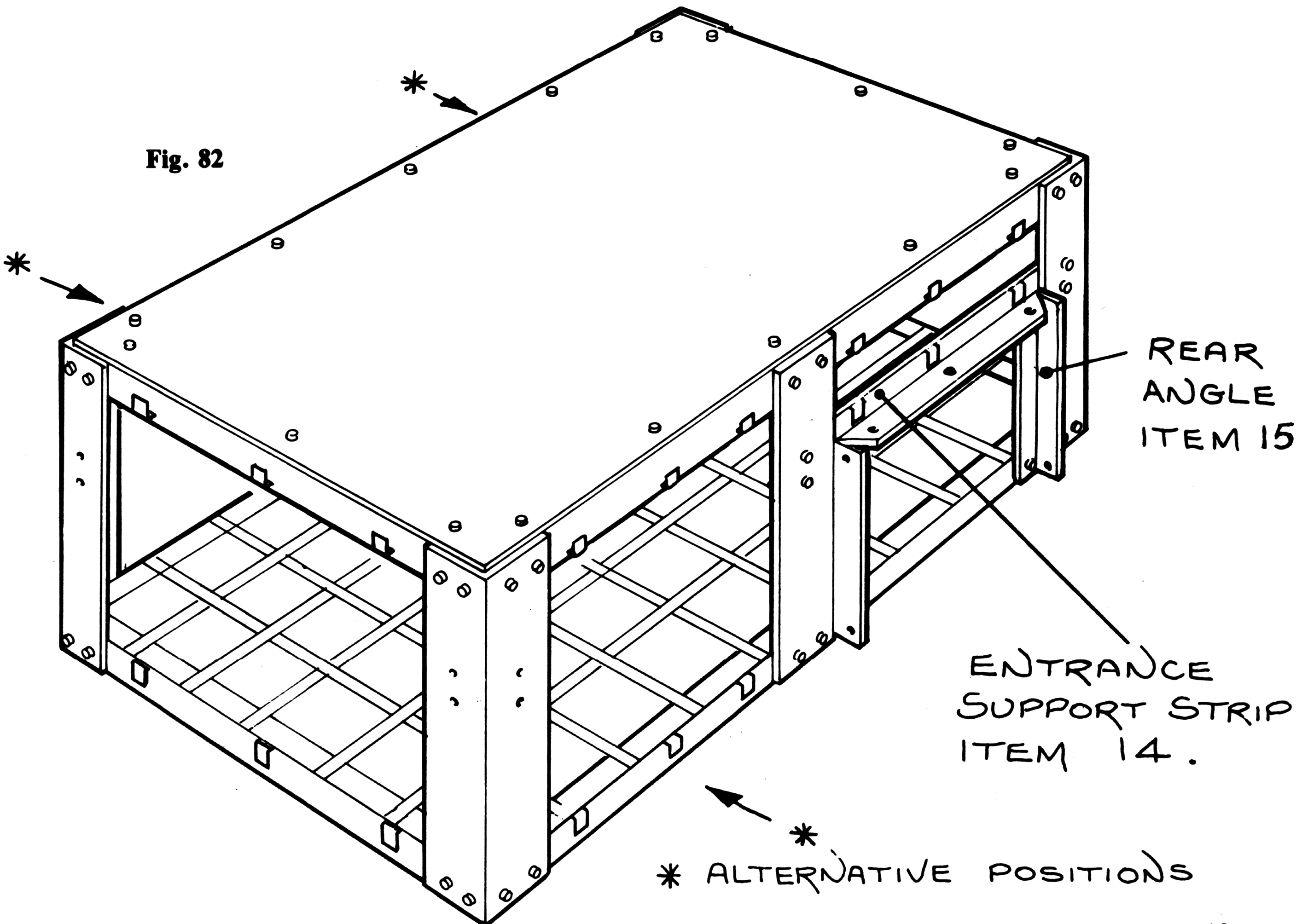
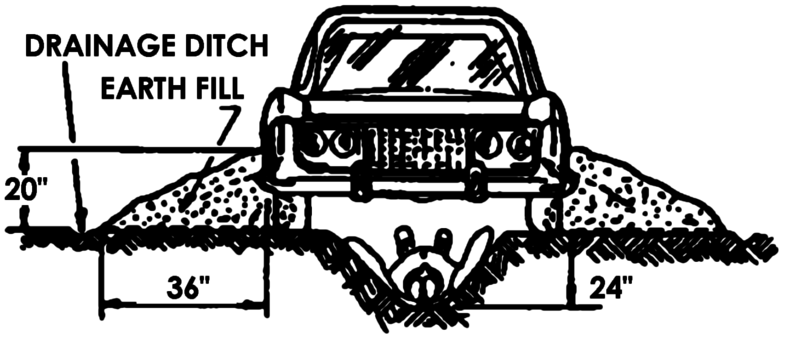


Fig. 82

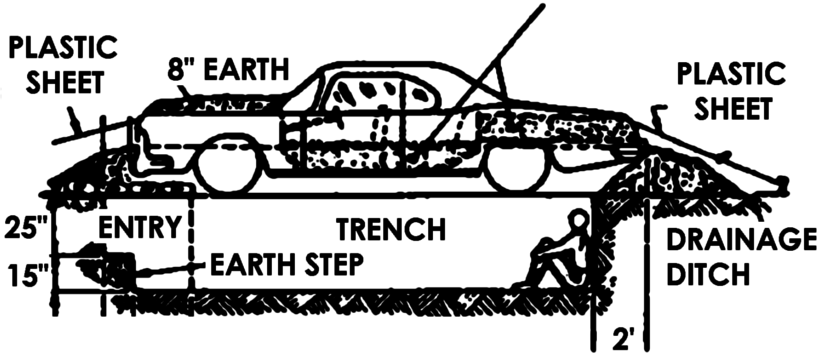

*
*
REAR
ANGLE
ITEM 15
ENTRANCE
SUPPORT STRIP
ITEM 14.
*
* ALTERNATIVE POSITIONS

CAR-OVER-TRENCH FALLOUT SHELTER (EXPEDIENT SHELTER HANDBOOK)



DOORS OR LOGS CAN BE USED IN PLACE OF CAR.

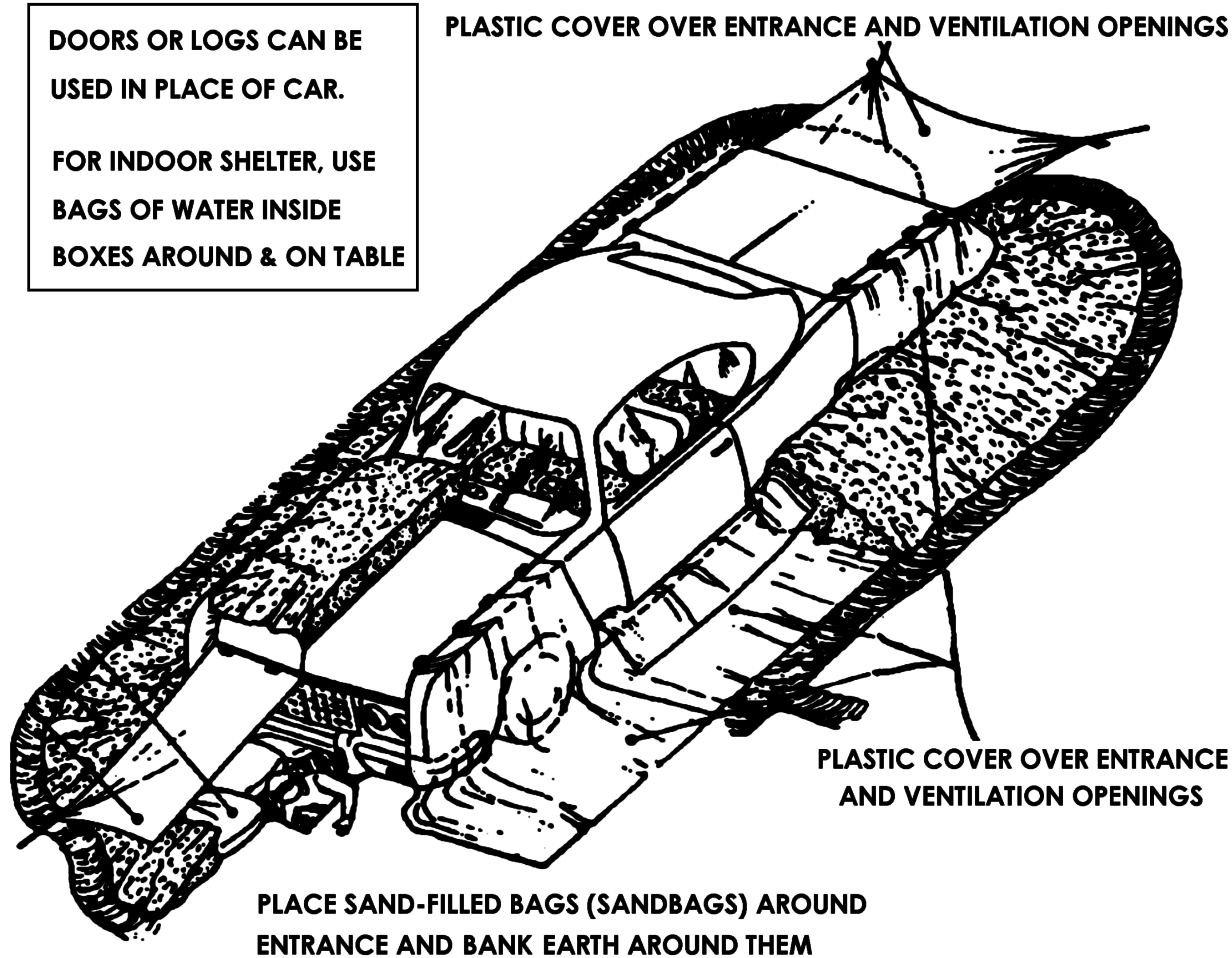
FOR INDOOR SHELTER, USE BAGS OF WATER INSIDE BOXES AROUND & ON TABLE



BANK EXCAVATED EARTH 20 INCHES HIGH AROUND CAR

PLACE 8" OF EARTH ON CAR HOOD

DIG SHALLOW DRAINAGE DITCH AROUND FILL



PLACE SAND-FILLED BAGS (SANDBAGS) AROUND ENTRANCE AND BANK EARTH AROUND THEM

HOME OFFICE

THE PROTECTION OF YOUR HOME AGAINST AIR RAIDS

READ THIS BOOK THROUGH
THEN
KEEP IT CAREFULLY

Why this book has been sent to you

If this country were ever at war the target of the enemy's bombers would be the staunchness of the people at home. We all hope and work to prevent war but, while there is risk of it, we cannot afford to neglect the duty of preparing ourselves and the country for such an emergency. This book is being sent out to help each householder to realise what he can do, if the need arises, to make his home and his household more safe against air attack.

The Home Office is working with the local authorities in preparing schemes for the protection of the civil population during an attack. But it is impossible to devise a scheme that will cover everybody unless each home and family play their part in doing what they can for themselves. In this duty to themselves they must count upon the help and advice of those who have undertaken the duty of advice and instruction.

If the emergency comes the country will look for her safety not only to her sailors and soldiers and airmen, but also to the organised courage and foresight of every household. It is for the volunteers in the air raid precautions services to help every household for this purpose, and in sending out this book I ask for their help.

Samuel Hoare

HOW TO CHOOSE A REFUGE-ROOM

Almost any room will serve as a refuge-room if it is soundly constructed, and if it is easy to reach and to get out of. Its windows should be as few and small as possible, preferably facing a building or blank wall, or a narrow street. If a ground floor room facing a wide street or a stretch of level open ground is chosen, the windows should if possible be specially protected (see pages 30 and 31). The stronger the walls, floor, and ceiling are, the better. Brick partition walls are better than lath and plaster, a concrete ceiling is better than a wooden one. An internal passage will form a very good refuge-room if it can be closed at both ends.

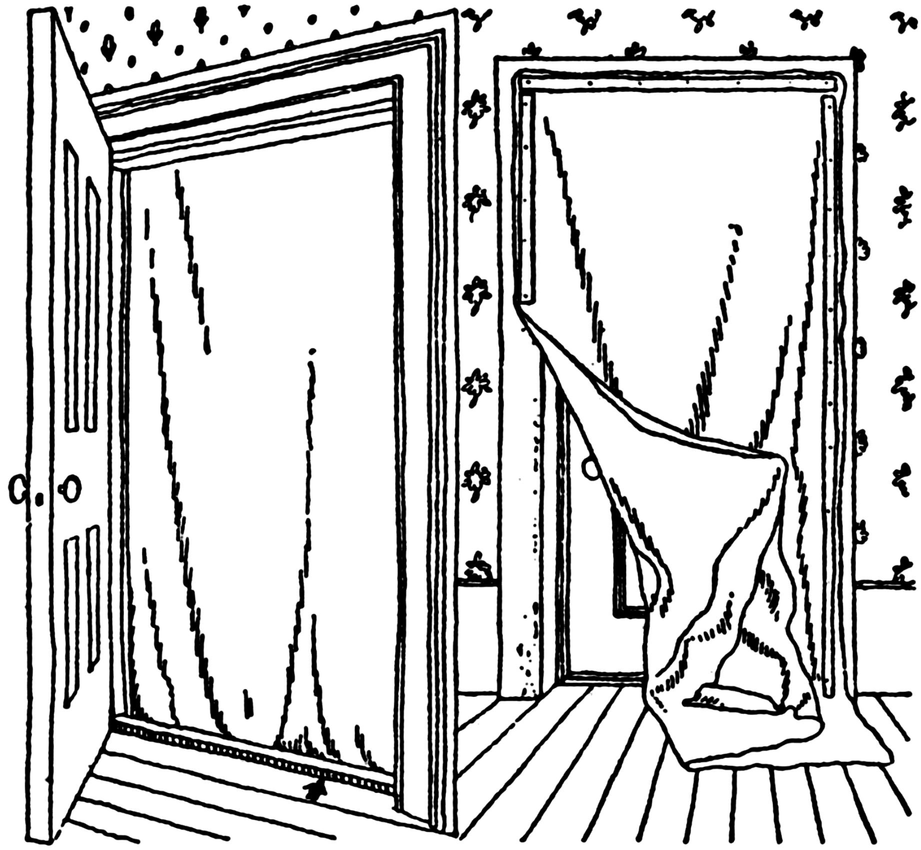
A cellar or basement is the best position for a refuge-room if it can be made reasonably gas-proof

The best floor for a refuge-room

A cellar or basement is the best place for a refuge-room if it can be made reasonably gas-proof and if there is no likelihood of its becoming flooded by a neighbouring river that may burst its banks, or by a burst water-main. If you have any doubt about the risk of flooding ask for advice from your local Council Offices.

Alternatively, any room on any floor below the top floor may be used. Top floors and attics should be avoided as they usually do not give sufficient protection overhead from small incendiary bombs. These small bombs would probably penetrate the roof but be stopped by the top floor, though they might burn through to the floor below if not quickly dealt with.

In a house with only two floors and without a cellar, choose a room on the ground floor so that you have protection overhead



How to seal up the door

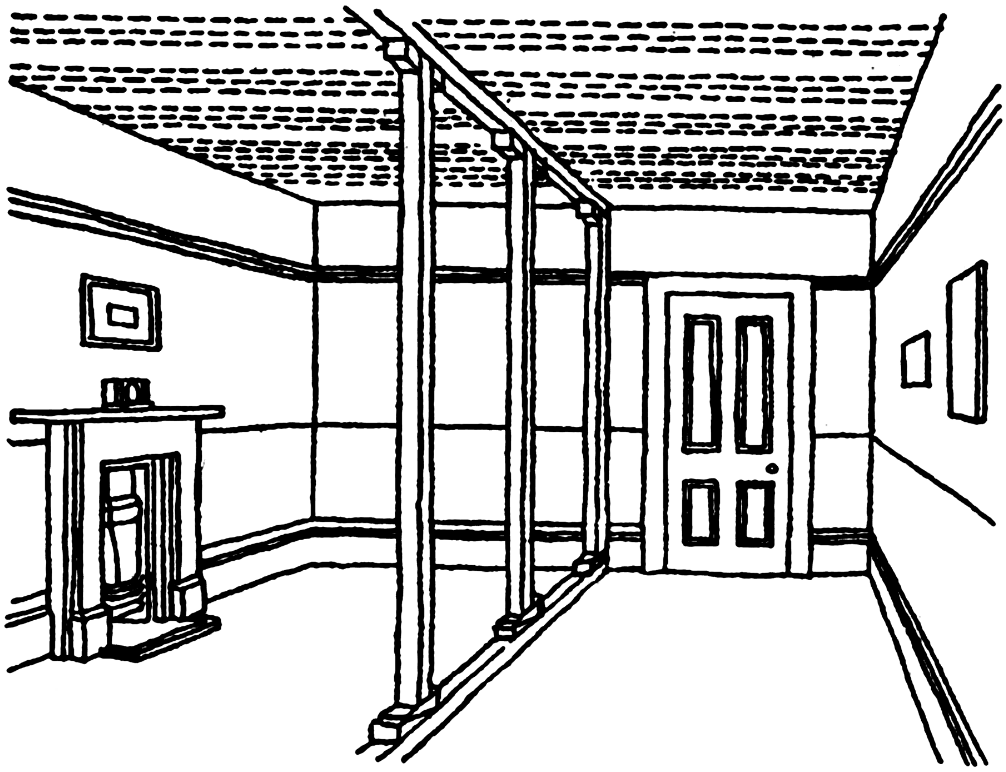
Doors which have to be opened and closed should be sealed against gas. This is how to do it.

Nail a piece of wood, padded with felt, to the floor so that the door, when closed, presses tightly against it. Take care not to nail this piece of wood on the wrong side of the door so that it cannot be opened. Strips of felt may also be nailed round the inside of the door to exclude draughts. Fix a blanket outside the door if the door opens inwards, or inside the door if the door opens outwards, with strips of wood. The top of the blanket should be fixed to the top of the door frame. One side of the blanket should be fastened down the whole length of the door frame, on the side where the hinges are, by means of a strip of wood nailed to the frame. The other side of the blanket should be secured not more than two feet down, so that a flap is left free for going in and out. Arrange the blanket so that at least 12 inches trails on the floor to stop air from blowing underneath it. See illustration above. If the blanket is kept damp during an air raid, it will give better protection.

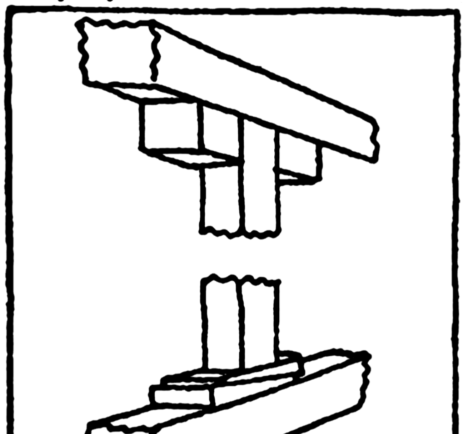
Strengthening the room

If your refuge-room is on the ground floor or in the basement, you can support the ceiling with wooden props as an additional protection. The illustration shows a way of doing this, but it would be best to take a builder's advice before setting to work. Stout posts or scaffold poles are placed upright, resting on a thick plank on the floor and supporting a stout piece of timber against the ceiling, at right angles to the ceiling joists, i.e. in the same direction as the floor boards above.

How to support a ceiling



The illustration below shows the detail of how to fix the props



The smaller illustration shows how the posts are held in position at the top by two blocks of wood on the ceiling beam. The posts are forced tight by two wedges at the foot, driven in opposite ways. Do not drive these wedges too violently, otherwise you may lift the ceiling and damage it. If the floor of your refuge-room is solid, such as you might find in a basement, you will not need a plank across the whole floor, but only a piece of wood a foot or so long under each prop.

How to deal with an incendiary bomb

You can tackle a small incendiary bomb yourself (better if you have someone to help you) if you will follow these directions. You will also be able to get proper instruction about it.

The bomb will burn fiercely for a minute or so, throwing out burning sparks, and afterwards less fiercely. It will set fire to anything inflammable within reach. You should try to deal with it before it has caused a big fire.

Before you can get close enough to do anything, you will probably have to cool down the room with water, preferably with a line of hose. (See page 20 for a simple hand pump.)

There are two ways of dealing with the bomb itself.

1 It can be controlled by means of the Stirrup Hand Pump (see page 20), with a *spray* of water which, although it does not extinguish the bomb, makes it burn out quickly and helps to prevent the fire spreading. Water must *not* be used on a bomb in any other way.

2 If it has fallen where you can get at it, it can be smothered with dry sand or earth. A bucket full of sand or earth is enough to cover and control a small bomb. The best method of applying it is by the Redhill sand container and scoop (see page 19); but a bucket will do if you have a long-handled shovel to use with it.

   Immediately the bomb is smothered, shovel or scoop it into the sand container or bucket and take it out of doors. If a bucket is used, 2 or 3 inches of sand or earth must be kept in the bottom to prevent the bomb burning through.

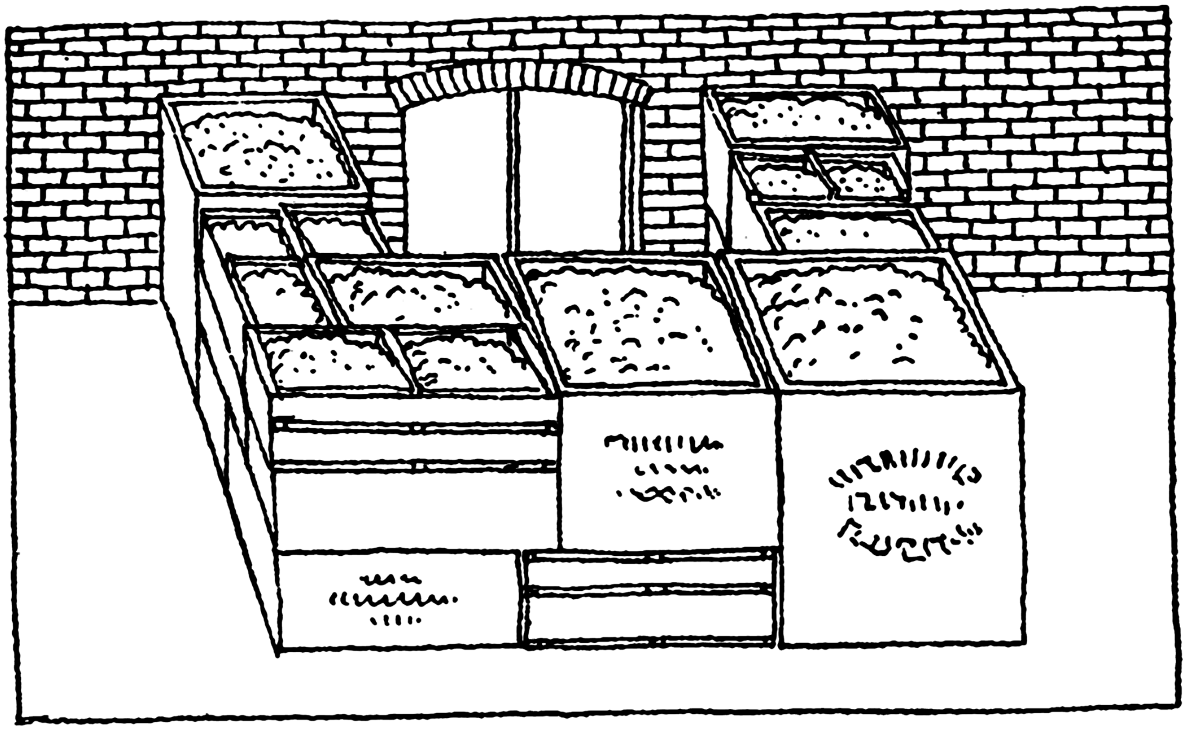
Remember that the bomb might burn through the floor before you have had time to remove it, and you might have to continue to deal with it on the floor below.

ACT PROMPTLY. PROMPT ACTION MAY BE THE MEANS OF SAVING LIVES. PROMPT ACTION WILL SAVE PROPERTY. PROMPT ACTION WILL PREVENT SERIOUS DAMAGE. PROMPT ACTION WILL DEFEAT THE OBJECT OF THE RAID.

EXTRA PRECAUTIONS AGAINST EXPLOSIVE BOMBS

TRENCHES. Instead of having a refuge-room in your house, you can, if you have a garden, build a dug-out or a trench. A trench provides excellent protection against the effects of a bursting bomb, and is simple to construct. Full instructions will be given in another book which you will be able to buy. Your air raid wardens will also be able to advise.

SANDBAGS. Sandbags outside are the best protection if your walls are not thick enough to resist splinters. Do not rely on a wall keeping out splinters unless it is more than a foot thick. Sandbags are also the best protection for window openings. If you can completely close the window opening with a wall of sandbags you will prevent the glass being broken by the blast of an explosion, as well as keeping out splinters. But the window must still be sealed inside against gas.



A basement window protected by boxes of earth

Any bags or sacks, including paper sacks such as are used for cement, will do for sandbags.

ALL persons involved in accidents suffer from shock, whether or not they suffer physical injury. Shock is a disturbance of the nervous system. It varies in its severity. The signs of shock are faintness, paleness, weak pulse, and weak breathing.

TREATMENT OF SHOCK

1 Place the patient flat on his back on a bed or a rug or on cushions. If you think a bone may be broken do not move the patient more than can be helped.

2 Loosen the clothing at the neck, chest and waist to make the breathing freer.

3 Cover the patient warmly with rugs and blankets. In cases of shock the body loses heat. A hot-water bottle is helpful, but take care that it does not lie in contact with the skin.

4 Give hot drinks. If you cannot make hot drinks, give cold water *in sips*. But only if the patient is conscious and able to swallow.

5 Soothe the patient by speaking reassuring words in a calm voice and in a confident way.

TREATMENT OF WOUNDS

The first thing to do is to stop the bleeding and to keep the wound clean. This can be done by covering it with a clean dressing bound on tightly. Do not touch a wound with your fingers because of the risk of poisoning from dirt. Treat the patient for shock in addition to attending to the wound, because the loss of blood, if the wound is serious, and the pain do in themselves cause shock.

WOUNDS IN THE HEAD AND BODY

1 Cover the wound with a clean folded handkerchief or a double layer of dry lint.

2 Apply another handkerchief or a layer of cotton wool as a pad to distribute the pressure over the wound.

3 Tie the dressing in position with a bandage, a strip of linen, or a necktie. This can be done quite firmly, unless there is any foreign body, especially glass, in the wound, or unless the bone is broken. In this case the dressing should be tied on lightly.

4 Treat the patient for shock.

ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

ORNL/TM-10423

Technical Options for Protecting Civilians from Toxic Vapors and Gases

C. V. Chester

Date Published - May 1988

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Office of Program Manager
for
CHEMICAL MUNITIONS
Aberdeen Proving Grounds, Maryland

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Table 1. Chemical Agent Toxic Properties[1]

Agent	Volatility (mg/m^3, 25^oC)	Median Lethal Concentration X Time (mg/m^3 *min) Respiratory	Percutaneous	Median Incapacitation Concentration X Time (mg/m^3 *min)
Chlorine (CL)	2.2×10^7	19,000	-	1,800
Phosgene (CG)	4×10^6	3,200	-	1,600
Hydrogen Cyanide (AC)	1×10^6	2,000-4,500	-	>2,000
Cyanogen Chloride (CK)	1×10^6	11,000	-	7,000
Sulfur Mustard (HD)[2]	920	1,500	10,000	200
Nitrogen Mustard (HN-1)	2,000	1,500	20,000	200
Lewisite (L)[2]	6,000	1,200-1,500	100,000	300
Mustard Lewisite (HL)	4,200	1,500	>10,000	200
Tabun (GA)[2]	610	400	40,000	300
Sarin (GB)[2]	22,000	100	15,000	35-75
Soman (GD)	3,900	100	1,000	35-75
VX[2]	10.5	100	1,000	50
Methyl Isocyanate		1500		

[1]Taken from U.S. Department of the Army (1975) and WHO (1970).

[2] Chemical agents in the stockpile to be destroyed in this program.

DISTANCE AND ATMOSPHERIC DISPERSION

As a toxic cloud moves downwind it mixes with ever increasing amounts of air, becoming larger and more dilute. Diffusion of the vapor vertically and at right angles to direction of motion reduces the exposure to someone standing in the path of the cloud. Diffusion forward and backwards along the direction of travel in general does not reduce the amount inhaled by someone in the path of the cloud.

The rate of vertical and lateral mixing of the toxic cloud with the surrounding air can vary enormously depending on weather conditions. A bright, sunshiny day promoting convection of the atmosphere close to the ground will cause rapid vertical mixing. A turbulent wind will promote lateral mixing. High windspeeds also reduce the time that a person is immersed in a passing cloud and directly reduces the amount they will inhale for given quantity going by. The worst conditions providing the greatest threat to people at the greatest distance downwind occur under conditions of light, steady winds, a clear night with cooling of the ground to cause vertical stability in the atmosphere and the existence of a temperature inversion not too far above the ground to trap the chemical close to the ground. Conditions very close to these were responsible for the large casualties at the Bhopal incident in India.

Figure 1 shows the downwind hazard from clouds of 1000 kilograms of each of several toxic gases moving at 1 meter per second (approx. 2 miles per hour) in a highly stable atmosphere (Pasquill type E). These conditions also assume an inversion at 750 meters. Calculations use the Army's D2PC code (Whitacre et al, 1986). The dependent variable in Fig. 1 is given as the protection factor offered by protective measures required to prevent 99 percent of the fatalities at each location downwind. For example for GB, to keep the dose down to 1 percent fatalities at 1 kilometer downwind, the population would have to have masks or other protection giving a protection factor of a little less than 700. The

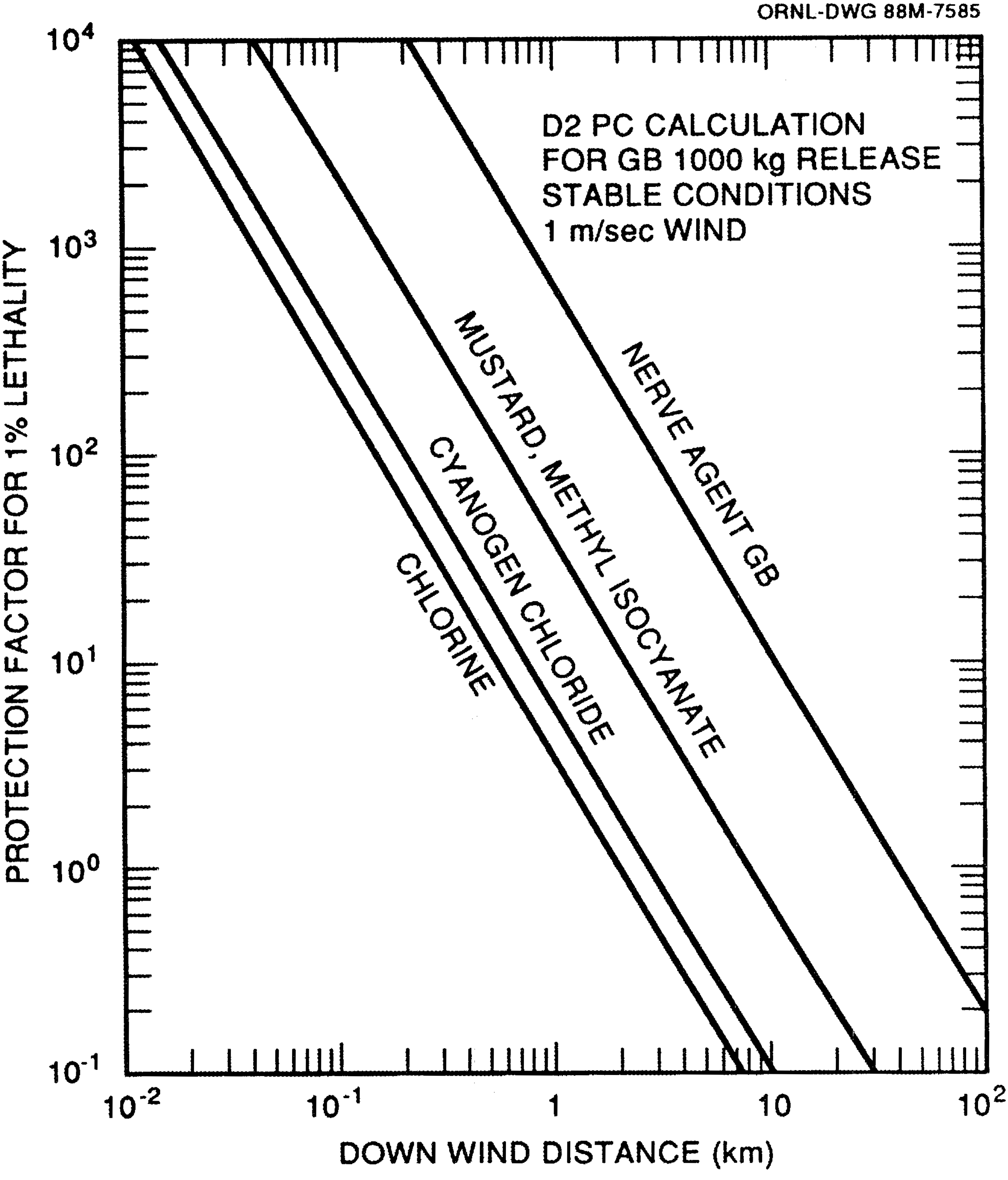

Fig. 1 Dose vs Downwind Distance for Some Very Toxic Gases

protection factor is the ratio of the dose people would get with no mask compared to what they would get if they were wearing a gas mask.

As can be seen from Fig. 1 the requirement for gas masks diminishes rapidly as one gets further away from the point of release of a quantity of agent. Under sunny conditions with a higher wind speed the requirement for protection would decrease even more rapidly. For the purposes of this study, these relatively pessimistic meteorological conditions (1.0 m/s. wind velocity, type E stability, inversion at 750 m) will be assumed in all cases.

EVACUATION

Evacuation is a way of increasing the distance between the population and a hazard and is the countermeasure to toxic chemical releases with which there is the most experience. Sorensen and his colleagues have reviewed the subject thoroughly (1987). It is very effective for slowly (few hours) developing hazards and in areas where emergency plans employing evacuation have been developed. Slowly developing chemical hazards can include a relatively small leak of a volatile toxic chemical, a large spill of a low volatility but highly toxic substance, or a progressive accident (e.g. fire) which doesn't at first cause release of toxic chemicals but has the potential of spreading to nearby equipment, tanks or drums containing toxics. Where small areas are threatened, evacuation can be quite effective.

Situations where taking shelter may be preferable to evacuating include quick release of small quantities of volatile toxic chemicals, or circumstances where an evacuation is likely to result in a traffic jam. This latter is a possibility where the area at risk is large, the population density is high, and the time available is short.

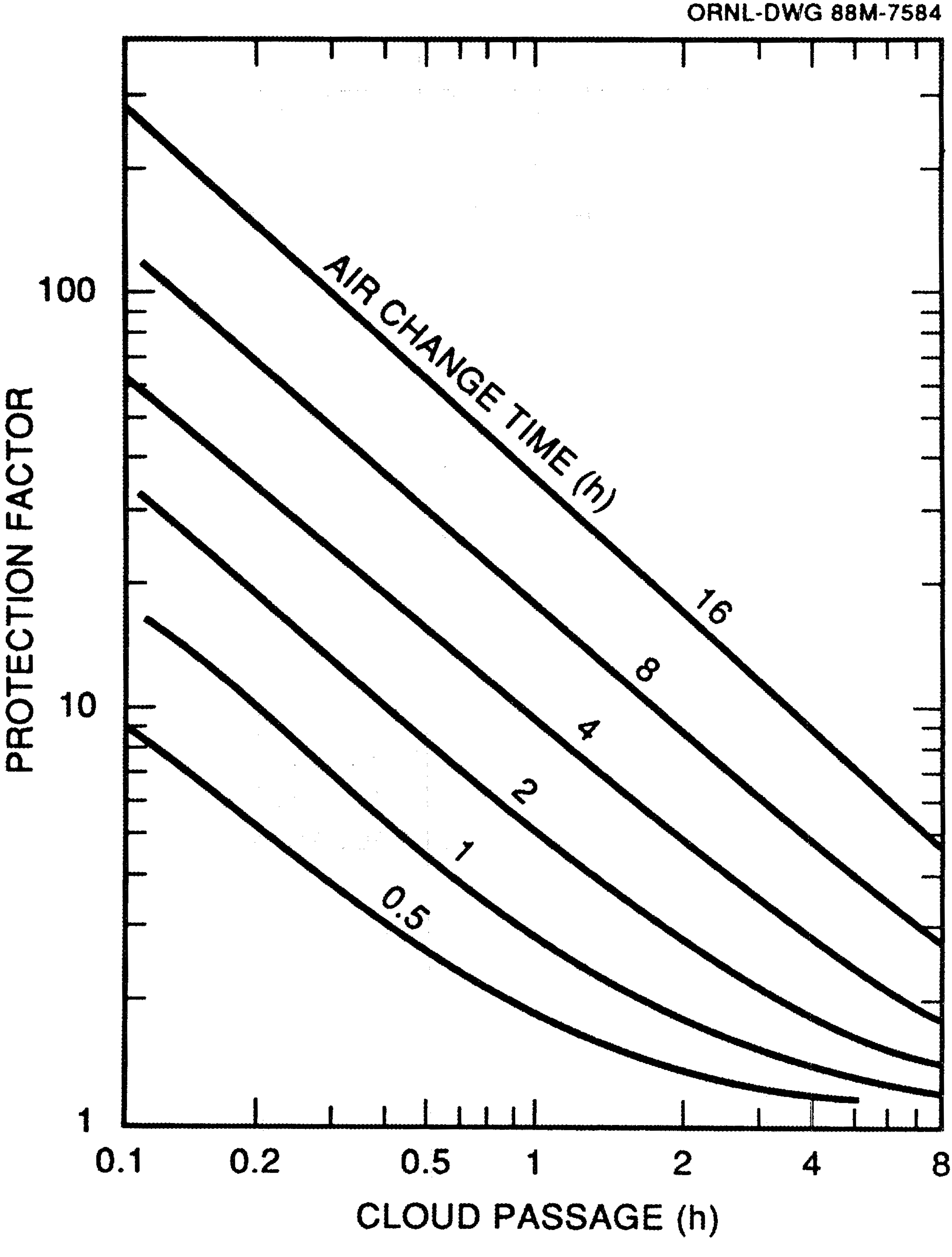

Fig. 2 Protection Factor of Leaky Enclosures

ORNL-DWG 88M-7581

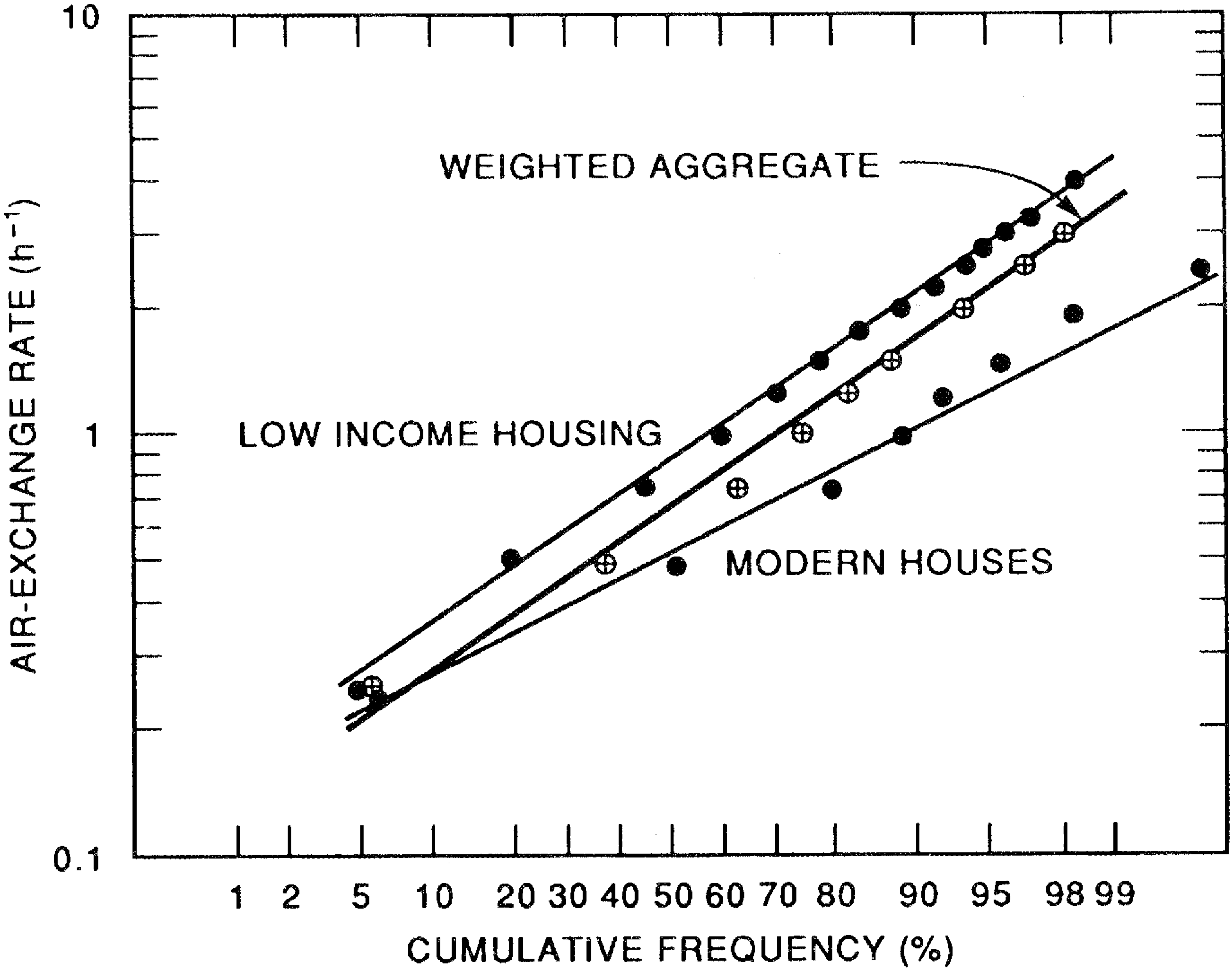

Fig. 3 Infiltration Rates of American Residences

Sorensen, J.H., 1988, Evaluation of Warning and Protective Action Implementation Times for Chemical Weapons Accidents, ORNL-TM/10437, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

U.S. Department of the Army 1975, Military Chemistry and Chemical Compounds, FM3-9/AFR 355-7.

Whitacre, G.C. et al, Personal Computer Program for Chemical Hazard Prediction (D2PC), U.S. Army Chemical Research and Development Center, Aberdeen Proving Ground, MD.

Wilson, D. J. 1987, Stay Indoors or Evacuate to Avoid Exposure to Toxic Gas, Emergency Preparedness Digest (Canada) 14 no. 1.

World Health Organization, 1970, Health Aspects of Chemical and Biological Weapons, Geneva, Switzerland.

ORNL/TM-2001/154

Energy Division

Will Duct Tape and Plastic Really Work? Issues Related To Expedient Shelter-In-Place

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Barbara M. Vogt

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Expedient sheltering involves the use of common materials to enhance the safety of a room inside a building against the impacts of a chemical plume. The central premise behind taping and sealing with duct tape and plastic is to reduce airflow into a room. Vapors penetrate into a room through cracks and openings in the walls, floors and ceilings, around doors and windows, and through openings for ducts, light fixtures, fans, pipes, electrical outlets, chimneys, door handles, and locks. The goal of taping and sealing is to significantly reduce infiltration at these points.

Expedient sheltering was suggested by NATO (1983) using the term “ad-hoc shelter” to protect civilian populations from chemical warfare agent exposure. The concept was to use plastic sheeting to seal off a room by fashioning a simple airlock at the entrance to the room and sealing off doors, windows or louvered vents. The NATO guidelines also stressed the need for rapid exit from the ad-hoc shelter once the plume had passed to avoid further exposure (NATO 1983, p. 143).

This strategy was further developed by the Israeli Civil Defense in the mid-1980s to protect the public against a chemical weapons attack (Yeshua 1990). The tape and seal strategy was in place when the Gulf War occurred in 1991 and received considerable media attention. The Israeli strategy was to have citizens prepare a “safe room” in their house or apartment with the use of weatherization techniques to permanently reduce infiltration. Citizens were also instructed to take expedient measures, such as sealing

doors and windows with plastic sheets, in the event of a chemical weapons attack. The use of plastic over a window was developed to reduce air infiltration and to provide a vapor barrier in the event of glass breakage from bomb explosions. A modification of the Israeli strategy was proposed for use in CSEPP (Sorensen 1988; Rogers et al. 1990).

Although vapors, aerosols, and liquids cannot permeate glass windows or door panes, the amount of possible air filtration through the seals of the panes into frames could be significant, especially if frames are wood or other substance subject to expansion and contraction. To adequately seal the frames with tape could be difficult or impractical. For this reason, it has been suggested that pieces of heavy plastic sheeting larger than the window be used to cover the entire window, including the inside framing, and sealed in place with duct or other appropriate adhesive tape applied to the surrounding wall.

Another possible strategy would be to use shrink-wrap plastic often used in weatherization efforts in older houses. Shrink-wrap commonly comes in a 6 mil (0.006-in.) thickness and is adhered around the frame with double-faced tape and then heated with a hair dryer to achieve a tight fit. This would likely be more expensive than plastic sheeting and would require greater time and effort to install. Because double-faced tape has not been challenged with chemical warfare agents, another option is to use duct tape to adhere shrink-wrap to the walls. Currently, we do not recommend using shrink-wrap plastics because of the lack of information on its suitability and performance.

3. WHY WERE THESE MATERIALS CHOSEN?

Duct tape and plastic sheeting (polyethylene) were chosen because of their ability to effectively reduce infiltration and for their resistance to permeation from chemical warfare agents.

3.1 DUCT TAPE PERMEABILITY

Work on the effectiveness of expedient protection against chemical warfare agent simulants was conducted as part of a study on chemical protective clothing materials (Pal et al. 1993). Materials included a variety of chemical resistant fabrics and duct tape of 10 mil (0.01-in.) thickness. The materials were subject to liquid challenges by the simulants DIMP (a GB simulant), DMMP (a VX simulant), MAL (an organoposphorous pesticide), and DBS (a mustard simulant). The authors note that simulants should behave similarly to live agents in permeating the materials; they also note that this should be confirmed with the unitary agents. The study concluded that "duct tape exhibits reasonable resistance to permeation by the 4 simulants, although its resistance to DIMP (210 min) and DMMP (210 min) is not as good as its resistance to MAL (>24 h) and DBS (> 7 h). Due to its wide availability, duct tape appears to be a useful expedient material to provide at least a temporary seal against permeation by the agents" (Pal et al. 1993, p. 140).

3.2 PLASTIC SHEETING PERMEABILITY

Tests of the permeability of plastic sheeting (polyethylene) challenged with live chemical warfare agents were conducted at the Chemical Defense Establishment in Porton Down, England in 1970 (NATO 1983, p. 133). Agents tested included H and VX, but not GB. Four types of polyethylene of varying thickness were tested: 2.5, 4, 10 and 20 mil (0.0025, 0.004 in., 0.01 in., and 0.02 in.). The results of these tests are shown in Table 1.

Table 1: Permeability of plastic sheeting to liquid agent

	Breakthrough time (h)	
Thickness	VX	H
0.0025	3	0.3
0.004	7	0.4
0.01	30	2
0.02	48	7

Source: NATO 1983, p. 136.

The data shows that at thickness of 10 mil or greater, the plastic sheeting provided a good barrier for withstanding liquid agent challenges, offering better protection against VX than for H. Because the greatest challenge is from a liquid agent, the time to permeate the sheeting will be longer for aerosols and still longer for vapors, but the exact relationship is unknown due to a lack of test data.

In Fig. 1 we plot the data in Table 1 to determine the nature of the relationship between thickness and breakthrough time. The data suggest a somewhat linear relationship, thus allowing some interpolation for various thickness of plastic sheeting. For reference, commercially available sheeting is typically sold at 0.7, 1, 1.2, 1.5, 2, .2.5, 3, 4, 6, and 10 mil. although thicker material is available (up to 100 mil). Plastic painter drop cloths are sold between 0.5 and 2 mil.

4. HOW HAVE THEY PERFORMED IN TESTS OR REAL EVENTS?

Although the "safe room" strategy was used in the many scud missile attacks against Israel in the Gulf War, no chemical agents were released during these attacks. Sheltering has been recommended as a protective action in several chemical releases in the United States and Canada. Some anecdotal information exists about sheltering effectiveness in those events, but no empirical studies of actual effectiveness in a real event have been conducted. Such data would be extremely difficult to capture. Two sets of experiments have been conducted on the effectiveness of in-place sheltering (Rogers et al. 1990; Blewett et al. 1996).

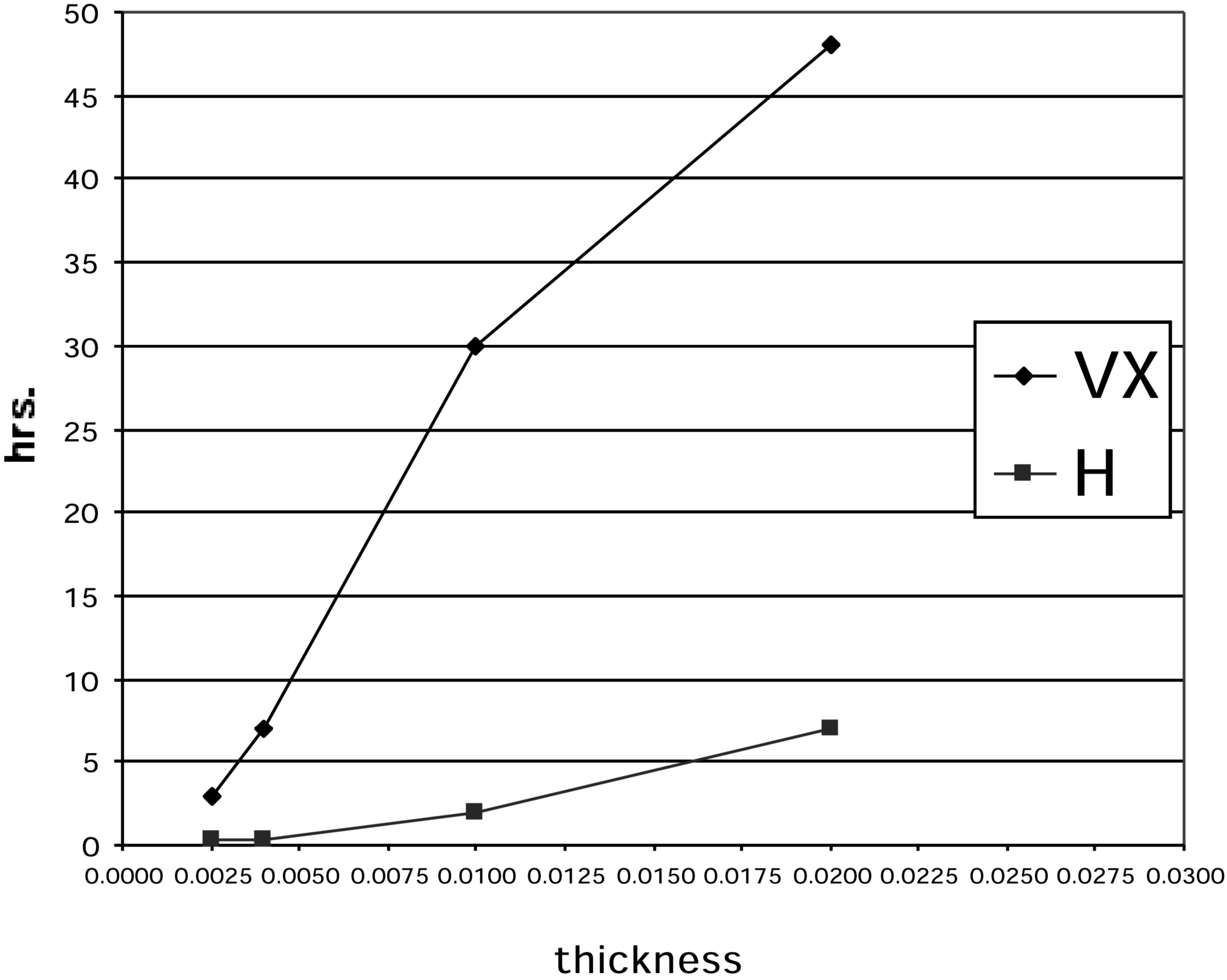

Fig. 1. Breakthrough as a function of the thickness of plastic sheeting.

The results of the two sets of experiments or trials using tracer gas methods provide some insight into the effectiveness of expedient sheltering. These trials were conducted in the vicinity of Oak Ridge, TN., in the late 1980s and Edgewood, MD in the mid 1990's. The Oak Ridge tests involved 12 single-family homes. The trials measured the air exchange for the whole house, the expedient room (mainly bathrooms) with a towel against the door, and the bathroom fully taped and sealed by a household member. Materials used included duct tape, flexible insulation cord, and plastic sheeting. In each test, subjects were given written instructions and checklists, but were left to make the decision how to seal the room.

Infiltration or air exchange is measured by the number of air changes per hour (ach). The average air exchange rate for the houses tested in the Oak Ridge trials was 0.45 ach. The bathrooms with a towel averaged only 0.94 ach. The fully sealed bathrooms averaged

0.33 ach, a reduction of 0.61 ach or 65% (0.61/0.94). One factor not assessed in the study was the air exchanged between the sealed room and the whole house versus the sealed room and the outside. If one assumes that the air exchanged by the room is mostly with the rest of the house, an added protection factor would be achieved because the contaminated air concentrations outside the house are reduced by mixing with air in the whole house and then reduced again in the expedient room. If it is assumed that most of the exchange is between the room and the outside, little added protection beyond that provided by the room would be achieved.

The tests in Edgewood, Maryland, involved 10 residential buildings and 2 mobile homes. Three types of rooms were tested: bathrooms with windows, windowless bathrooms, and walk-in closets. The expedient measures were applied by technicians, and the doors were taped from the outside of the room. A total of 36 trials were performed using different configurations of protection. The results (Table 2) show the air exchange rate for the whole house and for the room in which the expedient measure(s) was applied. The most aggressive strategy (Method 2) proved to be fairly effective, reducing average air exchange rates to between 0.15 and 0.21 ach.

Table 2: Results of Edgewood trials

Room and method	Average house ach	Average room ach
Bathroom—no expedient measures	0.29	0.27
Method 1: Bathroom—wet towel and taped vent	0.28	0.23
Method 2: Bathroom—door taped, plastic sheet on window, wet towel and taped vent	0.32	0.21
Windowless bathroom—no expedient measures	0.37	0.29
Method 1: Windowless bathroom—wet towel and taped vent	0.33	0.29
Method 2: Windowless bathroom—door taped, wet towel and taped vent	0.34	0.15
Walk in closet—no expedient measures	0.39	0.28
Method 1: Walk in closet—wet towel and taped vent	0.44	0.30
Method 2: Walk in closet—door taped, wet towel and taped vent	0.21	0.15

A good way of examining the numbers in the table is to compare the baseline case (door closed with no expedient protection) to the case with the greatest amount of expedient protection (Method 2). For the bathroom, the ach dropped from 0.27 to 0.21 (22%). For the windowless bathroom, the ach dropped from 0.29 to 0.15 (48%). For the closet, the ach dropped from 0.28 to 0.15 (46%).

The results of the two studies are consistent. Both studies showed a reduction of average air exchange rates from expedient protective measures. In some of the specific rooms tested such measures substantially reduced air infiltration into the sealed room when compared to the unsealed room. Infiltration was reduced in one trial by 90% in the

Oak Ridge study and by 57% in Edgewood study. In addition, fairly low air exchanges were achieved in some of the specific expedient room trials (0.11 ach in both studies). The effectiveness of individual trials varied. In the Oak Ridge study, the lowest reduction was 13% and highest air exchange rate was 0.58 ach. In the Edgewood study, the highest air exchange rate for the most aggressive strategy (Method 2) was 0.31 ach. The greater variability in the Oak Ridge data likely results from the variability in the way individuals implemented the taping and sealing, which was more uniform in the Edgewood study because taping was done in a consistent manner by a skilled technician.

5. TIMING OF EXPEDIENT SHELTER

In the ORNL study (Rogers et al. 1990), the time to implement the expedient protection was recorded. Overall times ranged between 3 and 44 min in total, with a mean of 19.8 min. The time to close up the house was relatively short, with a mean of 3.2 min with a range of 1 to 6 min. Times to tape and seal ranged between 2.3 and 38.6 min, with a mean of 16.7 min. These data are shown in Fig. 2.

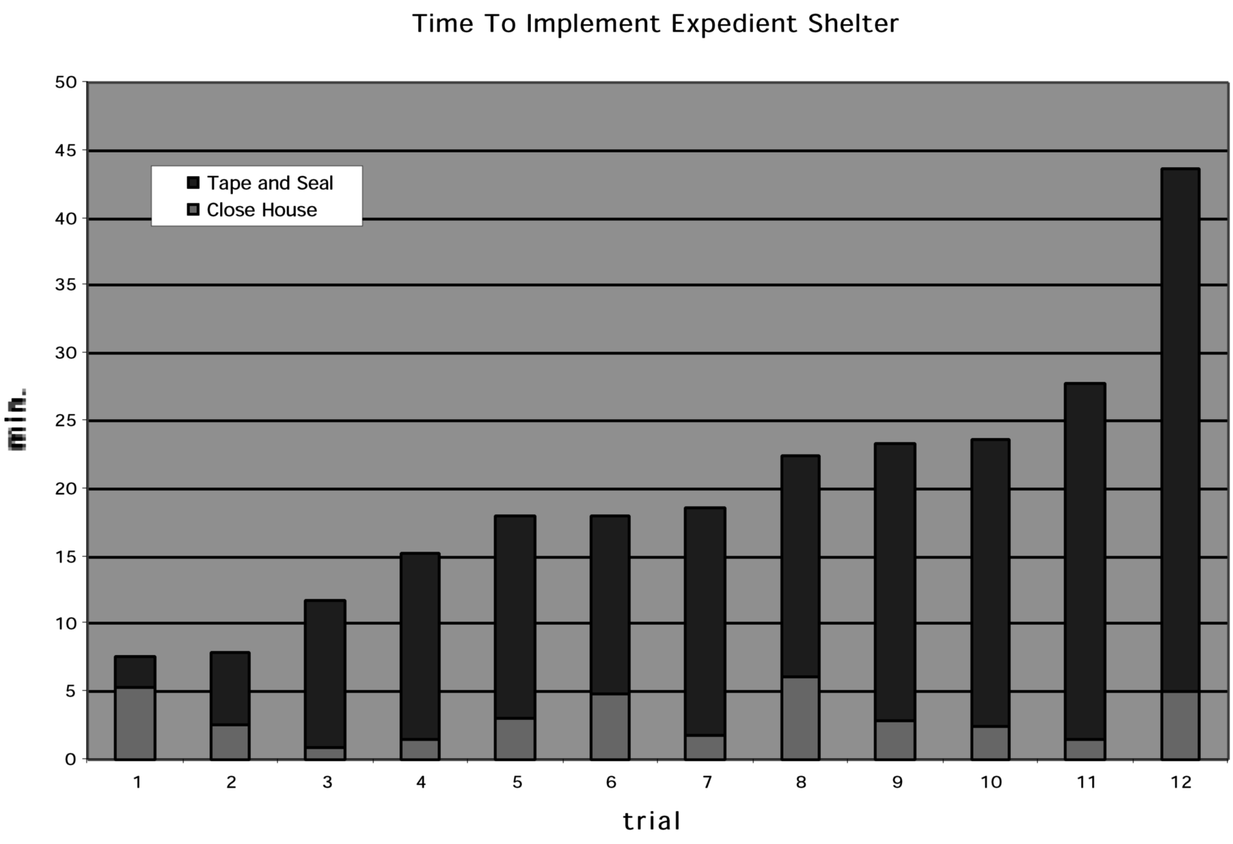

Fig. 2: Expedient shelter trial times.

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FINAL REPORT

11 March 1963

Recovery and Decontamination Measures after Biological and Chemical Attack

Contract OCD-OS-62-183

Prepared for
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Department of Defense

by

Science Communication, Inc.
1079 Wisconsin Avenue, N.W.
Washington 7, D. C.

To plan for countermeasures against any weapons one must understand the problem—the nature, the potentials, and the limitations. This research project and the resultant final report were intended to bring together current information most applicable to civil defense. It was particularly intended for those who are responsible for planning preparatory, reclamation and countermeasures effort to minimize the damage from a BW/CW attack.

William J. Lacy
Project Coordinator
Postattack Research

Decontaminants

An important class of decontaminants comprises the common substances or natural influences such as time, air, earth, water, and fire.

Natural Effects

Biological agents are living organisms and tend to die off with time unless they are in a favorable environment with moisture, food, warmth, and other factors necessary for their survival. In addition, most biological organisms are very sensitive to the conditions of temperature and humidity -- and, particularly to the ultra-violet portion of sunlight. Adverse exposure to the elements -- air, sunlight, high temperature, low humidity -- is effective, in fact, against all biological agents except the spore forms of bacterial organisms.

It is generally assumed that in the vegetative form bacteria (as contrasted to the spore form) can persist for less than two hours during daytime and about eighteen hours at night. Since these short-lived bacteria are the most probable agents, outdoor decontamination is usually not called for unless the agent has been identified, either by laboratory tests or by the character of the disease, as one which forms spores or is otherwise known to be persistent.

The persistent, low-volatile, agents such as the liquid nerve agents (V-agents) and the blister gases present the principal chemical decontamination problem. Even these evaporate in time. The speed of evaporation and dissipation is enhanced by higher temperatures and wind. Thus, if it is possible to avoid the area or the use of contaminated objects for a reasonable length of time, decontamination may be unnecessary. Such periods might run from hours to a few days, depending on the degree of contamination and weather conditions. In cold weather the agents will persist for longer periods.

Water

Next to weathering, the most important natural decontaminant is water, used either to remove the agent, with or without soap or detergents to assist, or by boiling. One caution -- water used to wash away contamination becomes contaminated and must be disposed of accordingly. Boiling destroys most chemical agents and all biological agents. When it is feasible, boiling is one of the most generally desirable methods -- particularly for household use by individuals.

Earth and fire, the other natural decontaminants, would have relatively little application in civil defense BW/CW decontamination operations. Earth may be used to cover contamination temporarily to keep it out of contact with people while natural processes either dissipate or destroy the agent. This involves substantial effort with bulldozers and earth-moving equipment and usually is neither practical or necessary.

Chemical Decontaminants

These are preferred when they are available. Chemical decontaminants fall in two classes -- those which destroy or neutralize the agents, and those which simply assist in their removal.

The principal decontaminants which destroy or neutralize are:

- Chlorine-containing materials, such as calcium hypochlorite (HTH) and sodium hypochlorite solutions. Many household disinfectants available under various brand names -- Clorox, Purex, etc. -- are sodium hypochlorite solutions.
- Alkalies, such as caustic soda (lye) and sodium carbonate (washing soda, or soda ash).

The chlorine-containing materials, in proper concentrations, are effective against both biological and chemical agents. As solutions they are used to decontaminate surfaces, as in washing off sealed food containers; for decontaminating cotton fabrics by soaking or addition during the washing process; and for sterilizing water. Hypochlorite solutions have the disadvantage of corroding metals and so must be rinsed off thoroughly.

The hypochlorites -- calcium and sodium -- are the preferred decontaminants for blister gases and liquid nerve agents. For most such applications they are used as solutions but for vertical surfaces or porous surfaces a "whitewash" of calcium hypochlorite (HTH), hydrated lime, and water (called a "slurry") is more effective

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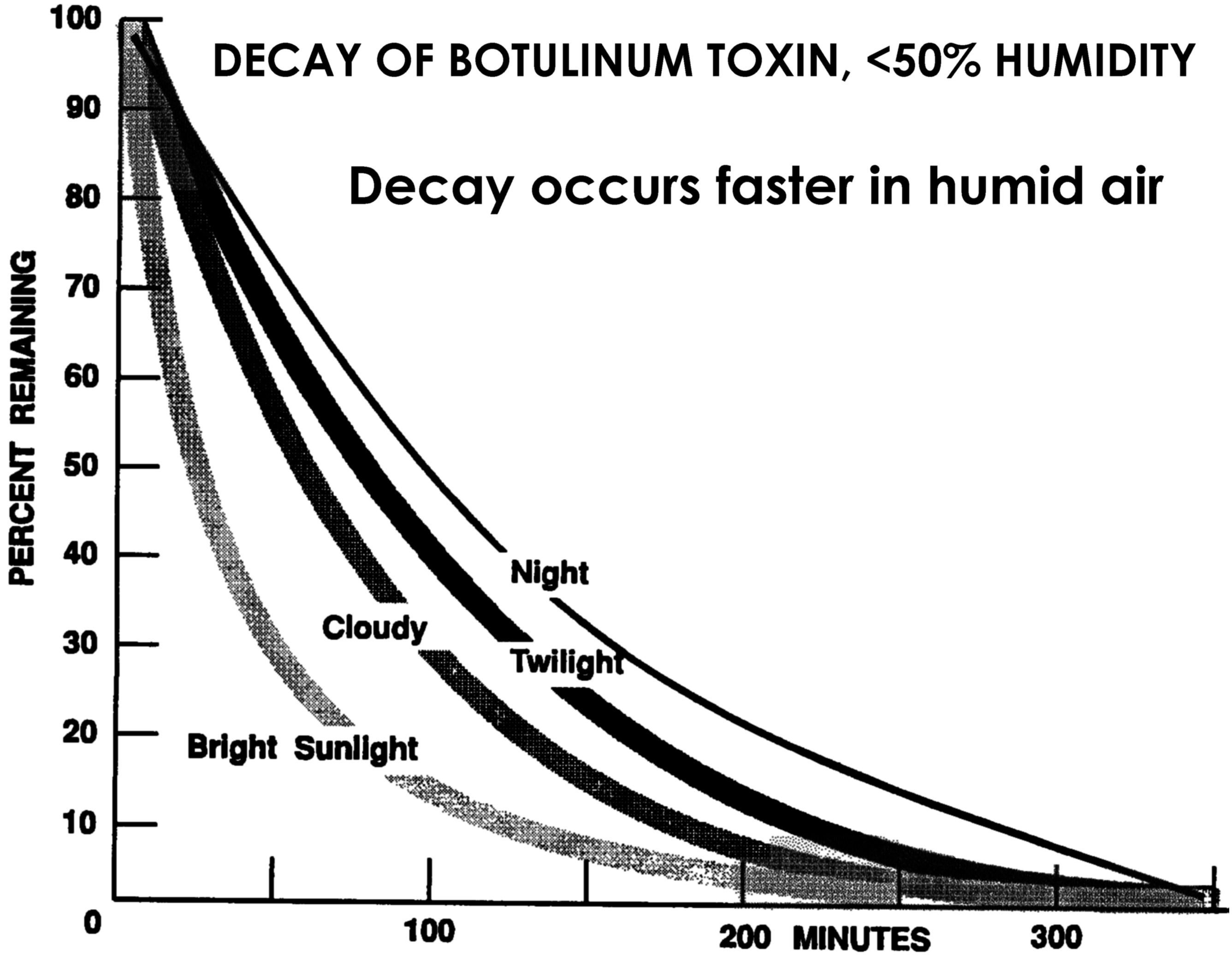
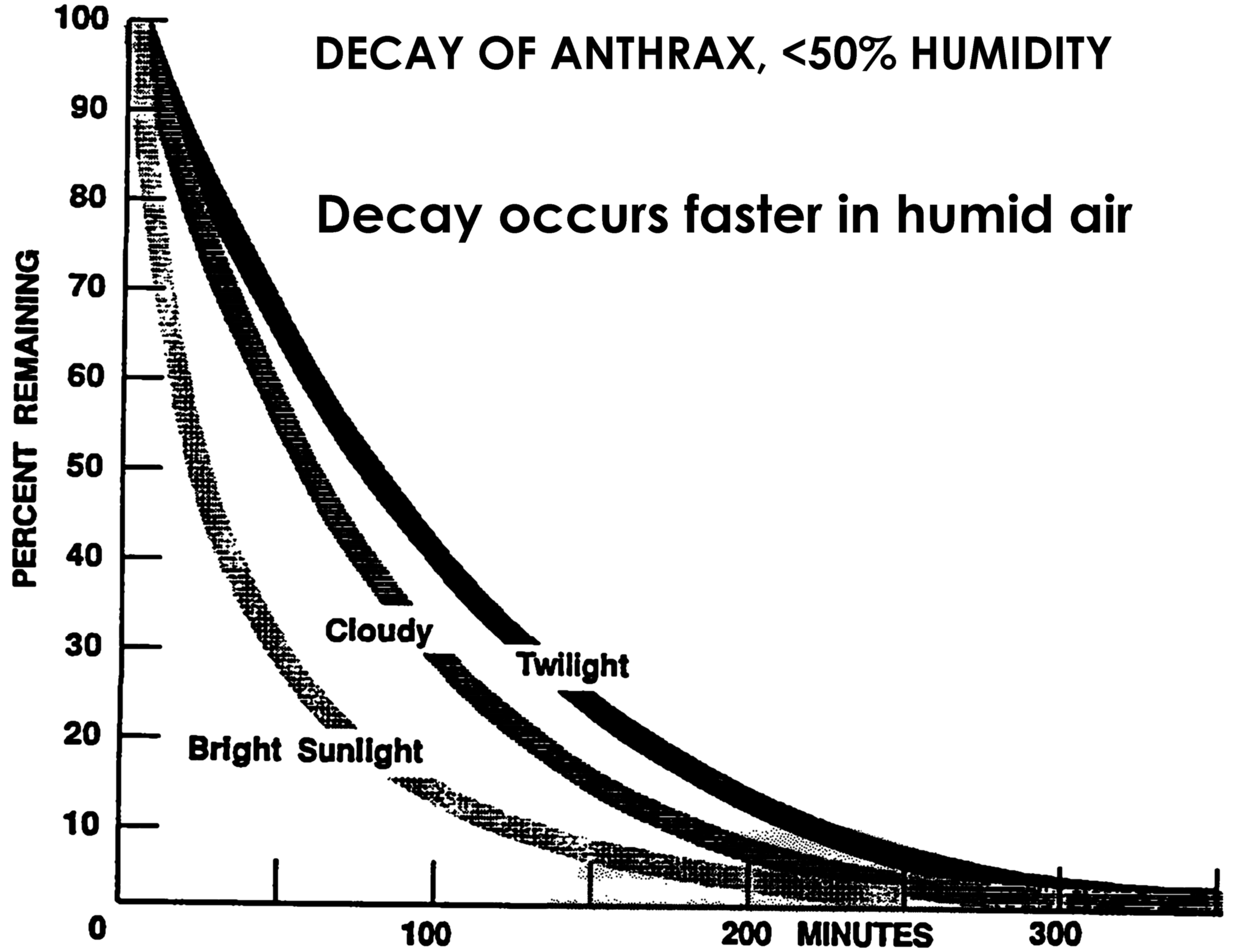


U.S. Army Field Manual FM 3-3 (1992), Fig. B-3.



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- Basic decontamination procedures are generally the same no matter what the agent. Thorough scrubbing with large amounts of warm soapy water or a mixture of 10 parts water to 1 part bleach (10:1) will greatly reduce the possibility of absorbing an agent through the skin.

Sealing a Room

- Close all windows, doors, and shutters.
- Seal all cracks around window and door frames with wide tape.
- Cover windows and exterior doors with plastic sheets (6 mil minimum) and seal with pressure- sensitive adhesive tape. (This provides a second barrier should the window break or leak).
- Seal all openings in windows and doors (including keyholes) and any cracks with cotton wool or wet rags and duct tape. A water-soaked cloth should be used to seal gaps under doors.
- Shut down all window and central air and heating units.

Suggested Safehaven Equipment

- Protective equipment—biological/chemical rated gas masks, if available; waterproof clothing including long-sleeved shirts, long pants, raincoats, boots, and rubber gloves.
- Food and water—a 3-day supply.
- Emergency equipment—flashlights, battery-operated radio, extra batteries, can or bottle opener, knife and scissors, first aid kit, fire extinguisher, etc.
- Most chemical and biological agents that present an inhalation hazard will break down fairly rapidly when exposed to the sun, diluted with water, or dissipated in high winds.

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Responding to a Biological or Chemical Threat IN THE UNITED STATES

In 1995, the Aum Shinrikyo, a Japanese religious cult, launched a large-scale chemical attack on the Tokyo subway system. The attack focused on four stations using Sarin gas, a potent chemical warfare nerve agent. Twelve people were killed but the attack fell far short of the apparent objective to inflict thousands of casualties. Subsequent investigation by authorities revealed that the cult had previously conducted several unsuccessful attacks against a variety of targets using other chemical agents and the biological agents botulism toxin and anthrax.

More recently, the incidents of anthrax contamination in the United States served to illustrate the viability of this type of terrorist threat. Again, the attacks fell short of mass casualties, but some deaths did occur and the fear and disruption caused by a few positive anthrax findings were crippling. The U.S. Government continues working to meet the potential consequences of such attacks.